THIN-SECTION MICROMORPHOLOGY OF EIGHT OREGON SOILS

by

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THIN-SECTION MICROMORPHOLOGY OF EIGHT OREGON SOILS

Introduction

Understanding of natural phenomena as complex as soil is necessarily limited by the extent to which we recognize component parts and their interrelationships. Since a great many components of most soils are too small to be readily studied with the naked eye, microscopic examination provides a logical extension of normal field observation and description.

Progress in petrology and physiology during the last century has been tremendously facilitated by microscopic investigation of the complex materials under consideration. Comparable advances in pedology cannot be expected until soil is widely studied in detail sufficient to resolve those complex, interacting constituents, organic and inorganic, living and dead, which constitute the enigmatic earth-air interface we call soil.

In its broadest sense this study is an attempt to illustrate some of the answers which may be expected from petrographic investigation of soils. In a narrower sense it is an attempt to extend traditional profile description to a microscopic level of detail. As more criteria are made available by which soils may be compared, more meaningful evaluation of like and unlike individuals should become possible.

Historical

From the very advent of petrographic microscopy in the early nineteenth century, geologists have made constant use of this technique (13, p. 10). Pedologists began to apply a petrographic approach in studying soil during the first quarter of this century. Interest in this field, however, has been sporadic. The efforts of Kubiena in Europe; Cady in this country; and, more recently, Brewer, in Australia have stimulated interest in pedological petrography, but it is not yet widely accepted as essential to the study of soils.

Choice of Soils

To direct petrography's small, bright light most effectively at Oregon soils it was desirable to begin by studying a selection that encompassed the wide range of soils within the state. Since the Soil Conservation Service and Oregon Agricultural Experiment Station had already compiled a list of "Benchmark" soils ("important and extensive soils that ...... illustrate a great part of the range of soil conditions existing within the state,")[1], the following series were chosen from this list: 1. Astoria, a "Brown Latosol" from sedimentary rocks; 2. Quillayute, an Ando soil from silty alluvium; 3. Jory, a Reddish-Brown Lateritic soil from basalt; 4. Woodburn, a Prairie soil from silty alluvium; 5. Dayton, a Planosol from silty alluvium; 6. Walla Walla, a Chestnut soil from loess; 7. Tolo, a Regosol from volcanic ash; and 8. Lookout, a Brown soil from basalt.

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[1]Unpublished, in-service, Soil Conservation Service memo, dated 4/11/60.

Methods

Air dried, oriented clods were selected from each horizon and impregnated with a mixture of equal parts "Laminac"[2] resin and acetone, using a modification of the proceedure recommended by Cady (personal communication). The viscosity of this mixture is low enough that clods of less than six cubic centimeters were successfully impregnated without resorting to evacuation. For exceptionally dense peds the proportion of acetone was increased. After evaporation of the acetone, treated clods were slowly heated to 100 degrees centigrade and cooked at that temperature for one hour. Thin sections were prepared from impregnated clods in the standard manner, with the exception that dry grinding on abrasive paper gave cleaner sections than wet grinding with abrasive powder.

Format

Profile descriptions of soils studied herein have been included to emphasize that micromorphological description is merely more detailed and essentially similar in nature. For the same reason, description of thin sections proceeds from lower (35x) to higher (640x) magnifications. Greater enlargement is possible (1000 to 1500x), but interpretation of features observed at this level would be just as conjectural as the image was magnified.

In all cases, thin section samples were obtained from the locations given in the accompanying profile description.

[2]A polyester resin manufactured by Cyanamid Corp., Stamford, Conn.

Horizons which are essentially similar to those adjacent, have been excluded from thin section descriptions in an effort to minimize needless repetition. In the case of soils lacking contrasting horizons, some repetition is inevitable.

Photomicrographs are included which illustrate micromorphologic aspects of soil or show features of interest from the standpoint of pedogenesis or provenance.

Munsell color names have been used as faithfully as variation in light source allows.

Sand and silt-size intervals used are taken from the Soil Survey Manual (21, p. 207). Thickness ranges for coatings is as follows: very thin - $<10\mu$, thin - 10 to 100μ, thick - 100 to 500μ, very thick - $>500\mu$.

All thin sections are vertical and the interval covered is given along with the horizon designation.

Illustrations are in plane light except where otherwise indicated.

Description of Thin Sections

Astoria silt loam A_{11} 5-6"

Low power. The dark brown, subangular, medium to very fine granular peds of this horizon are more definite in outline than those of lower horizons. Margins of most peds are more dense than interiors and contain a smaller percentage of silt grains.

Medium power. Dark reddish brown mycelia are very common in larger peds and, together with an abundance of partially decomposed plant tissue, give the dark color characteristic of this horizon. Mineralogically, the silt and sand fraction is essentially the same as in lower horizons. Granular peds cannot readily be resolved into sand and silt-size aggregates, as in lower horizons. These minute aggregates occur sparingly in voids between larger peds.

High power. No striking differences in the nature of matrix and very fine silt particles within it are evident when compared with lower horizons. The percentage of skeletal particles is somewhat higher but the matrix material itself appears identical with that lower in the profile.

Astoria silt loam A_{12} 10-11"

Low power. Fine and very fine subangular blocks are composed of sand-size granular aggregates of silt, clay, organic matter and sand. Darker and lighter peds from higher and lower levels respectively make up approximately one fifth of this horizon. Pieces of charcoal are larger and more numerous than at lower levels.

Roots, some of them mycorrhizal, account for approximately 10%, and interstitial voids 50%, of the section. Subangular to subrounded, sand-size, dark reddish brown shot are rare but more numerous than at greater depths. Silt-size feldspar grains occur (see Quillayute A_{12}).

High power. Granular aggregates differ only slightly from those in the B_{21}. A large quantity of silt-size fragments of charcoal, decomposing wood, and reddish brown mycelia account in large part for the darker color of this horizon.

Astoria silt loam B_{21} 15-16"

Low power. Dark yellowish brown, sand-size, granular aggregates of silt, clay, sand and organic matter are randomly packed into fine, subangular blocky peds with from 40 to 70% in interstitial pore space. Sand-size rock fragments of chloritized, fossiliferous shale and pieces of charred wood are common minor constituents. Fairly dense, coarse, granular aggregates of yellowish brown material from lower horizons make up at least 10% of this one.

Medium power. In contrast to the sand-size shale fragments, approximately one percent of the horizon consists of angular silt-size plagioclase. Granular aggregates are as variable in density as the subangular peds which they form. Margins of most peds are indistinguishable from their respective interiors. A few of the denser ones have very thin, irregular and discontinuous coatings of very pale, yellow material of very low birefringence with yellow, highly birefringent, very fine silt-size flecks. Tubular pores as such are lacking, but similar features, loosely filled with granular aggregates, are common.

High power. Thin (5 to 10μ) reddish brown mycelia are common and penetrate most larger aggregates. They are associated with silt-size cellular masses similar in color and are mycorrhizal on some roots in the thin section.

Astoria silt loam B_{22} 26-27"

Low power. Very fine, yellowish brown to dark yellowish brown, subangular, blocky peds are composed of aggregated clay, silt and sand, which displays a wide range in degree of compaction. Darker, more granular aggregates resemble those from higher horizons; lighter more compact aggregates, those from lower horizons. Fragments of the underlying rock dominate the skeletal fraction. A few dense, subrounded, dark reddish brown, sand-size, sesquioxide concentrations (shot) are present.

Medium power. Surfaces of most peds are coated discontinuously with silt-size spheroidal blobs of isotropic material. They vary from pale yellow, with low positive relief and more or less included skeletal material, to clear and pale green with moderate, positive relief. The latter type is rare relative to the former. A significant part of the organic matter occurs as sand-size particles of charcoal. Mycelia are much less common than in upper horizons.

High power. Matrix material consists of silt-size fragments of highly birefringent clay shale surrounded by pale yellow, isotropic material of low positive relief.

Astoria silt loam B_3 44-45"

Low power. "Inclusions of material from adjacent horizons" are mentioned in the profile description and thin-sections emphasize the point. The general impression is that the whole mass has been stirred. Sand-size particles of clayey tuffaceous shale and chloritized fossils (foraminifera?), in various stages of disintegration, are mixed in a matrix derived from similar shale. Many pores have become filled with smaller aggregates. Lumps and swirls of matrix material which are darker than average are very common. Tubular pores (.1 to .5 mm) and interstitial voids between aggregates, in roughly equal proportions, make up 40 to 50% of the section. The aggregates are also highly porous.

Medium power. Irregular silt-size aggregates of matrix material commonly occur on the walls of pores. Where pore walls are coated with a very thin coating of slightly oriented clay, the identity and transitory nature of these aggregates is obvious. Larger aggregated accumulations in pores are only distinguishable from the general ground mass by paucity of sand-size fragments.

Angular sand and coarse silt-size grains of quartz, feldspar, and quartz-feldspar intergrowth are present only in minor quantities ($<3\%$)

compared with fragments of clay shale from local bedrock.

Most smaller voids appear to be interstitial between aggregates which are packed together in such a way that the horizon looks massive.

High power. Clays of both high and low birefringence are evident in fragments of bedrock, usually in separate fragments. The ground mass consists of highly birefringent, very fine silt-size, yellow to orange particles in a matrix which is almost clear and has very low refractive index and birefringence.

Very thin unlaminated coatings of clear, pale yellow, moderately birefringent material occur on some surfaces. With nicols crossed, these coatings have gradual boundaries at best and, with plane light they are indistinguishable from matrix material. There is a striking resemblance between these ped peripheries and that illustrated in the "7th Approximation" as an example of a ped surface in a cambic horizon (20, p.42). Silt-size, spheroidal blobs of isotropic, pale green material, displaying moderate, positive relief, are sparsely distributed on major ped surfaces.

Astoria silt loam C 60-61"

Subangular, gravel-size fragments of tuffaceous shale, mostly altered to montmorillonitic clay, are surrounded by aggregated material similar to that dominating the horizon above.

Fig. 1
Astoria silt loam B_{21} 15-16"
150μ

1. Pores 2. Darker, organic rich aggregated material 3. Yellowish brown aggregates with pale yellow, isotropic colloform coatings.

Fig. 2
Astoria silt loam B_{22} 26-27"
150μ

1. Spheroidal blobs of isotropic material 2. Pores 3. Yellowish brown, dense, aggregate 4. Dark yellowish brown, organic rich aggregates

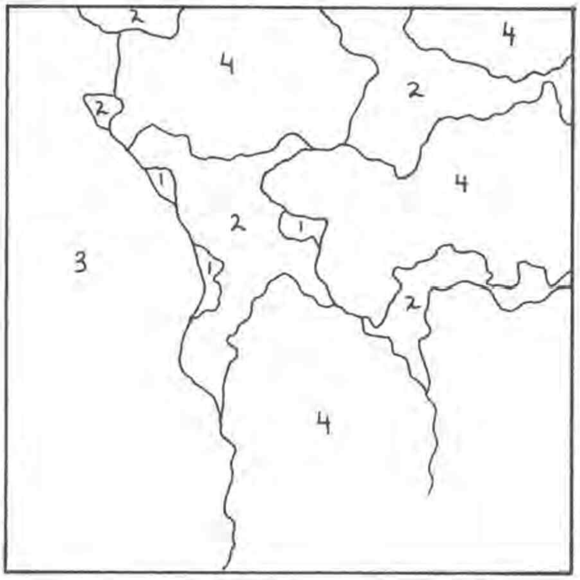
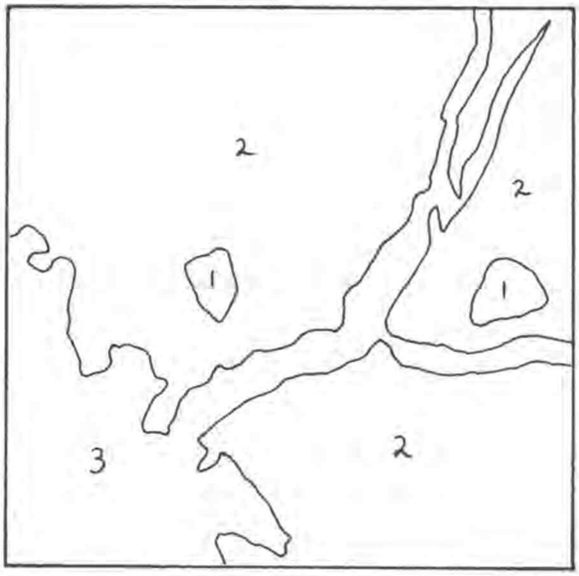
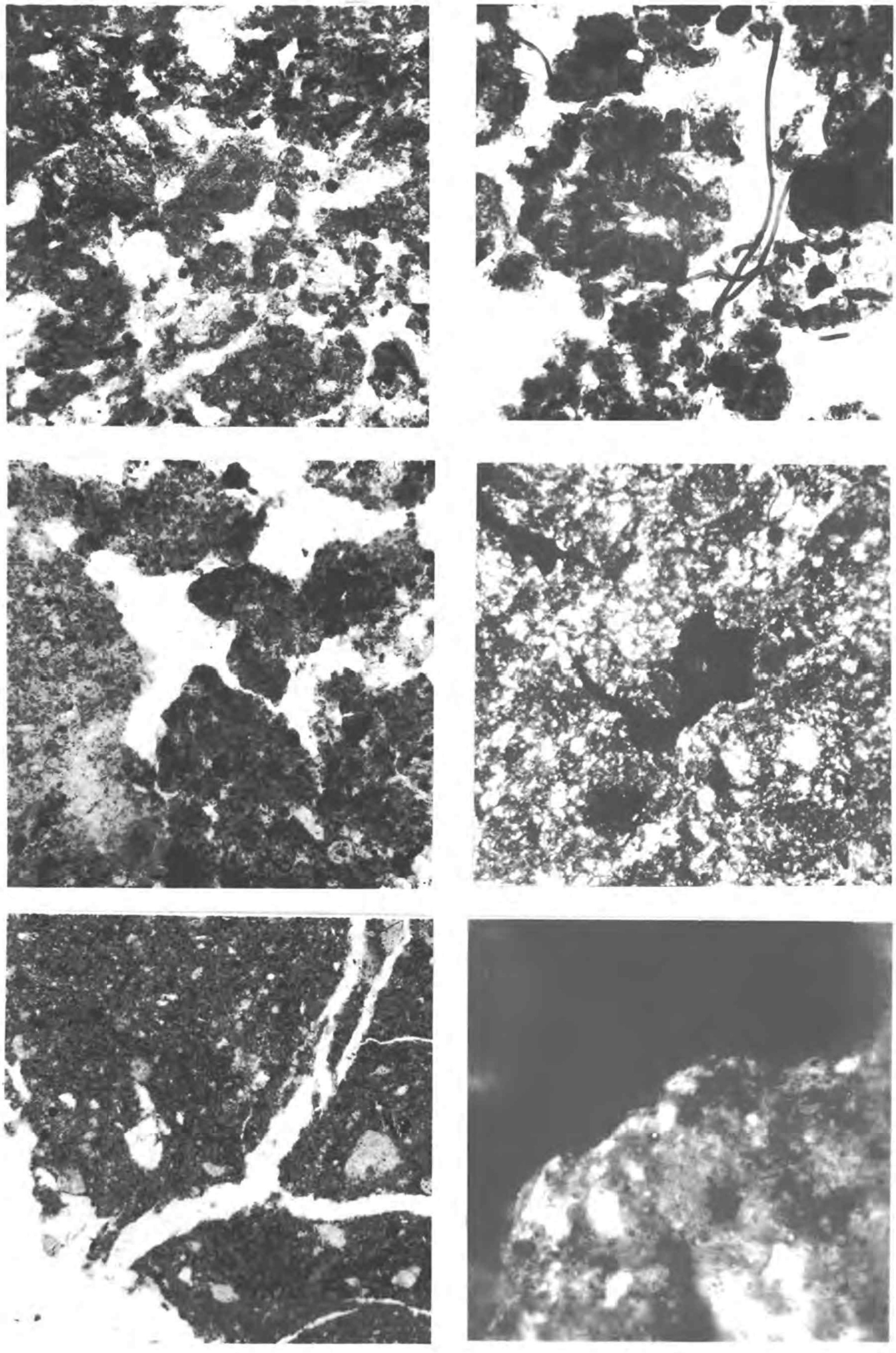


Fig. 3
Astoria silt loam B_3 44-45"
150μ

1. Sand grains 2. Dense matrix, a mixture of yellowish brown and dark yellowish brown materials 3. Pore space





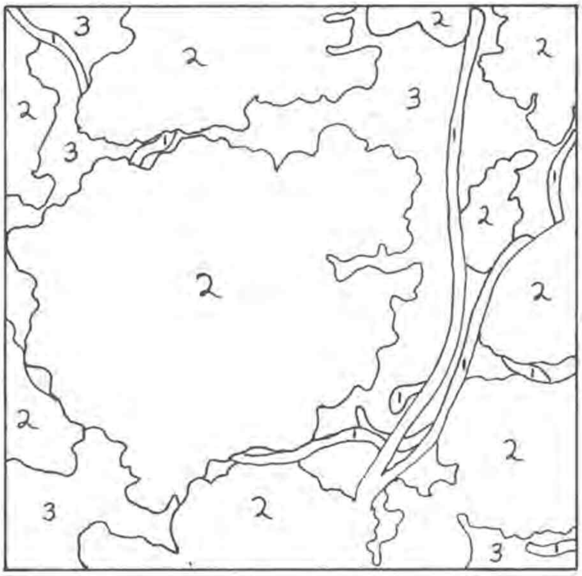


Fig. 4
Astoria silt loam B_{21} 15-16"
50 μ
1. Reddish brown fungus mycelia
2. Dark yellowish brown granular aggregates of silt size spheroidal blobs 3. Interstitial pores

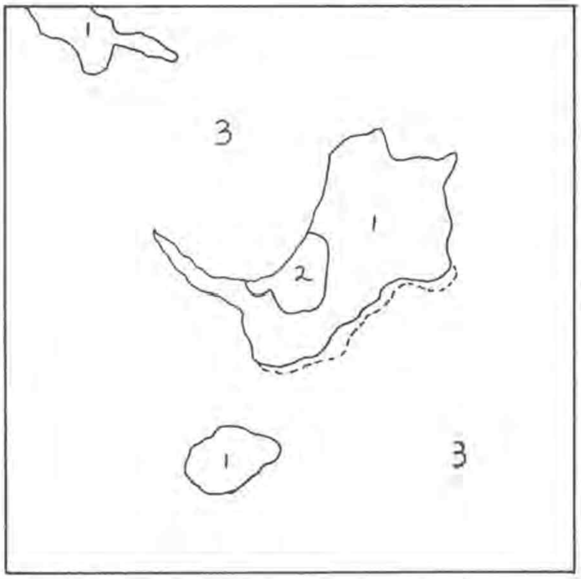


Fig. 5 polarizers crossed
Astoria silt loam B_{22} 26-27"
50 μ
1. Pores 2. Isotropic blob containing silt grains 3. Matrix, containing particles of highly birefringent clay

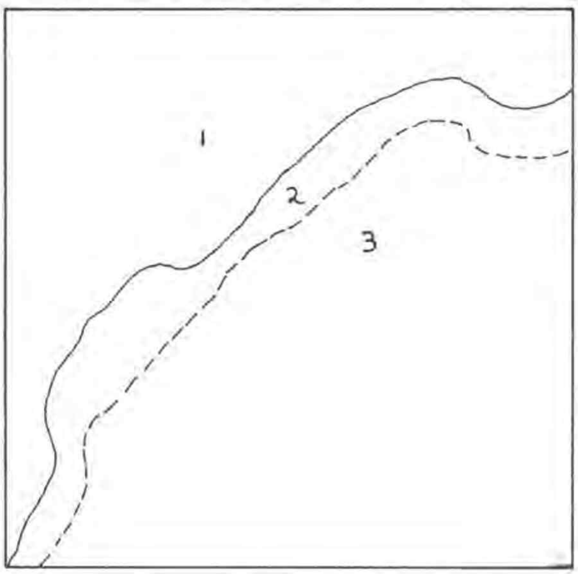


Fig. 6 polarizers crossed
Astoria silt loam B_{22} 26-27"
10 μ
Enlarged central portion of Fig. 5
1. Pore 2. Slightly oriented clay particles in pore wall. 3. Matrix

Interpretation

Without exception features observed suggest a youthful soil, both physically and chemically. Present rates of vertical mixing seem to keep pace with processes which tend to differentiate horizons, resulting in the gradational profiles characteristic of "Coast Range" soils. Microscopic evidence as to which mixing mechanisms are of greater importance is no less equivocal than field observations have been. Profile and thin section descriptions alike mention pores of various sizes loosely filled with aggregated material from neighboring horizons. Both roots and animals are undoubtedly responsible for such pores. Since all of these soils occur in youthful topography of moderate to considerable relief, mass movement is an undeniable contributor to profile instability. It should also be borne in mind that normal vegetation in this area is dominated by dense forests of large trees. During any thousand year period significant volumes of soil are profoundly disturbed by the uprooting of trees.

Presence of pyroclastic plagioclase in upper horizons, similar to that occurring in the Quillayute profile, suggests that the two soils are of approximately equivalent age. The respective surfaces must have closely resembled the present ones at the time of deposition. Differences in rate and mode of mixing could easily account for small differences in ash distribution between the two profiles.

Grains of quartz and quartz-feldspar intergrowth are similar to, but less abundant than, those in Quillayute. Such grains most logically originate from the more acid intrusives of the Coast Range.

Mechanism of emplacement within this profile is enigmatic.

Although thin-sections do not offer direct evidence that profound chemical changes are lacking, the relative abundance of silt and sand-size particles in upper horizons, which are identical with those in parent material is strong indication that chemical alterations alone do not dominate development of this profile. Crystalline clay minerals present in the soil, appear to be present also in the rather soft, weathered tuffaceous shales from which the soil derives. A large part of the soil clay could very well result from comminution of local bedrock with little or no chemical alteration. The pale yellow, isotropic material (allophane?) present in the matrix might well derive either from volcanic ash, parent material, or both. Since the ash fall for which there is evidence was probably less than one inch thick it seems reasonable to assume that the bulk of the isotropic matrix material was derived from a more abundant source. The weathered shale on which the present profile occurs is more plentiful than all other possible source materials combined.

Features similar to the birefringent flecks surrounded by isotropic material, which are noted in the B horizons of Astoria, have been described (montmorillonite within allophane) from soils occurring on islands belonging to New Zealand (25, p. 32).

Kaolinitic clays are generally acknowledged (8, p. 340) to be more stable under acid humid conditions than montmorillonitic types. According to calculations of Siever (19, p. 131), for every three parts of montmorillonite converted to kaolinite two parts of silica are produced. Even if half the clay-size fraction of the profile were assumed to be colloidal silica, such a process could easily account for it, in view of the large proportion of montmorillonitic parent material.

Colloidal material undoubtedly moves downward within the profile, probably as globular aggregates within major pores. The magnitude of this translocation is difficult to estimate optically, since the mobile aggregates are virtually indistinguishable from the matrix in general when they become tightly packed.

Description of Thin Sections

Quillayute silt loam A_{11} 6-7"

Low power. Dark brown to very dark brown granular aggregates of silt, sand and organic matter, ranging from coarse to medium sand-size, are set in a loose matrix of silt-size granular aggregates. Interstitial pore space between the smaller aggregates accounts for at least 50% of the section. Pore space in larger aggregates is less than 10%. Fine tubular pores, usually occupied by grass roots, are common, but most of the total porosity is interstitial between the finest granules. There is no noticeable difference in the constituent components of aggregates of different size. Rounded, very coarse, sand-size lumps of material from the B horizons are present, but make up less than 5% of the section.

Medium power. Sand and silt grains of quartz, plagioclase and augite are angular and subangular while rock fragments tend to be subrounded. A few fine sand-size fragments of plagioclase are covered with a thin coating of pumiceous glass. Dark brown coloration appears to be due both to minute opaque, organic particles and to organic stains. Thin-walled spherical pollen grains, probably from grass, occur commonly in interstitial voids.

High power. Granular aggregates do not appear to have peripheries distinctly darker or denser than interiors. A few aggregates give the impression of having lighter colored, more transparent edges. Matrix material within the smallest aggregates is light yellowish brown and isotropic or nearly so. Grass opals are rare and quite often broken. Glass shards occur but are rare and difficult to detect. Minute ($\sim 5\mu$) opaque particles of decayed organic matter are a major constituent of the horizon.

Quillayute silt loam A_{12} 16-17"

Low power. Dark brown, very fine, subangular blocky, to fine and very fine granular peds are composed of sand-size granular aggregates of silt, organic matter and clay. Granular aggregates are much more loosely packed than in lower horizons. Tubular pores are very common, and present a wide range in the extent to which they are filled with granular aggregates. Some are empty, others so crammed as to be virtually indistinguishable from the surrounding ped. A few lumps of material from the B horizons are present, but they make up less than 10% of the total volume of this horizon. Since these lumps are coated with dark granules they would be difficult to distinguish in the field. Pore space is principally interstitial between granules.

Medium power. Skeletal components differ very little from those in lower horizons except for occasional fine and very fine sand-size plagioclase crystals enveloped in vesicular glass. Mineral grains are clean or coated with aggregated material without any apparent regard for size, shape or lithology. Dark brown color of the horizon derives from minute particles of organic matter, much of which is charred wood. Weathered shale fragments similar to those found in the Astoria silt loam thin-sections are the most common component of the sand fraction.

Quillayute silt loam B_1 26-27"

Low power. Brown, fine to medium, subangular blocky peds are composed of subrounded sand-size granular aggregates of silt, clay and organic matter. Degree of compaction varies considerable, but average peds are less dense than in deeper horizons and constituent granular aggregates are more easily distinguished. Inclusions of material from the A horizons are striking due to their darker brown color and high content of sand-size fragments of charred wood. Shot are present but are fewer, smaller, less regular in outline and have less distinct boundaries than those in the B_2 horizon. Walls of tubular pores are noticeable darker brown and more densely packed than ped interiors. Sand-size rock fragments are subrounded while silt and very fine sand particles are angular.

Medium power. At least 20% of the granular aggregates are sufficiently dark brown to suggest that they originated in the A horizons. The darker granules tend to be less densely packed than the lighter brown material of the B_1 proper, in some cases filling obvious tubular pores in lighter peds.

High power. Granular aggregates are composed of angular, coarse and fine silt grains in a matrix of light yellowish brown clay of very low birefringence. Etched clinopyroxene grains similar to those in lower horizons are present. They are usually coated with matrix material to such an extent that the degree of etching is difficult to determine. Darker brown colors appear to be caused mostly by very small (<10μ) particles of organic matter. Very thin, discontinuous coatings of clay were not observed.

Quillayute silt loam B_{21} 38-39"

Low power. Yellowish-brown, medium and fine, subangular to angular blocks are composed of sand size aggregates of silt and clay. Rounded and subrounded, fine to coarse sand-size shot are common. Quartz, feldspar, quartz-feldspar intergrowth, clinopyroxene and weathered rock fragments are also important members of the coarser sand fraction. Tubular pores and cracks all contain varying quantities of fine granular aggregates and larger peds are constructed of similar aggregates displaying a wide range in density.

Medium power. Clinopyroxene grains exhibit terminal etching characteristic of this group of minerals. Spaces which apparently reflect the original grain shape usually occur adjacent to the etched surface. Peripheral spaces do not occur around quartz grains or rock fragments. Tubular pores are common and their walls are more compact than ped interiors. Some pore walls and parts of ped surfaces show a tendency to become darker and deficient in coarse particles toward the outer edge.

High power. Matrix material consists of yellow, equidimentional, highly birefringent particles less than 2 in diameter which are in turn embedded in a clear, very pale yellow substance which is either extremely low in birefringence or isotropic and has low positive relief. Very thin, ($<10\mu$) discontinuous and irregular coatings of this matrix mixture occur on surfaces of some peds.

Quillayute silt loam B_{22} 52-53"

Low power. Yellowish brown, medium to fine angular to subangular blocks are composed of granular aggregates of silt, clay and sand, packed together so as to give a massive appearance. Most pore space within peds is interstitial between groups of these sand-size granular aggregates. Tubular pores are partially filled with similar loosely packed, though slightly darker, aggregates. Sub-rounded, sand-size shot are, numerically, the most important single constituent of the sand fraction.

Medium power. Angular fragments of weathered shale similar to that described in the Astoria profile are common in the sand and silt fraction. Quartz, clinopyroxene, shot, feldspar and biotite are conspicuous also. Although rock fragments are weathered in varying degree there is no positive indication that such weathering occurred in the present situation. Clinopyroxenes are etched in a manner similar to those in the horizon above, but to a lesser degree.

High power. Clay making up silt-size shale particles is yellow, with moderate to high birefringence, that in the matrix is pale yellow with low to very low birefringence. Very thin ($<10\mu$),

Fig. 7
Quillayute silt loam A_1 6-7"
50μ

1. Interstitial pores 2. Dense aggregates 3. Loosely aggregated silt, organic matter and clay

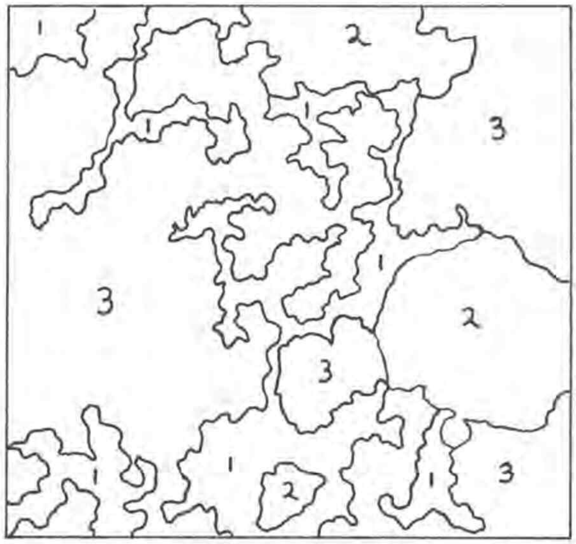


Fig. 8
Quillayute silt loam B_1 26-27"
50μ

1. Coarse silt grains 2. Interstitial pores 3. Aggregated silt, clay and organic matter

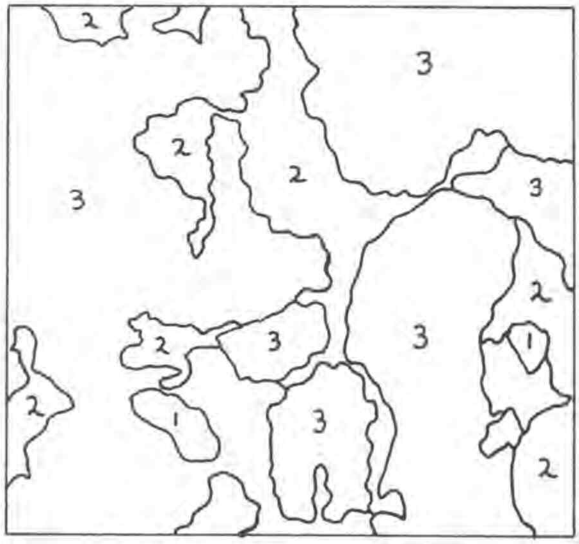
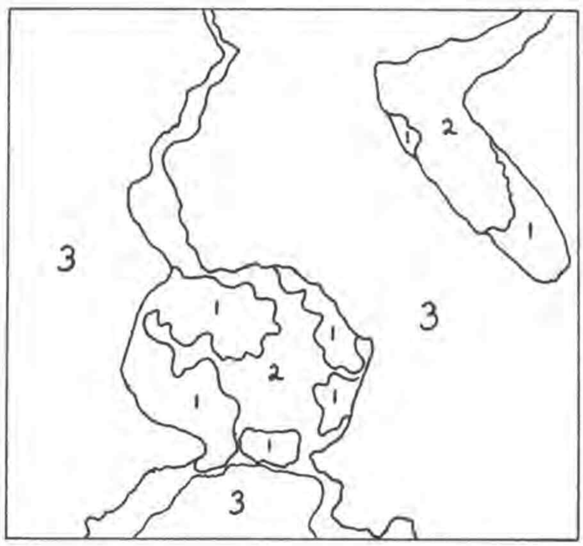
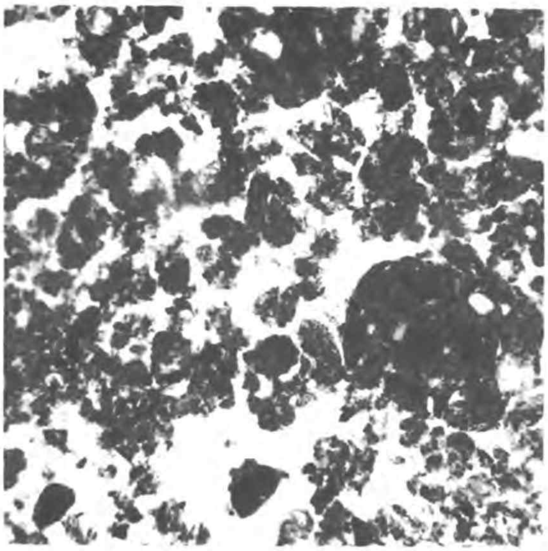
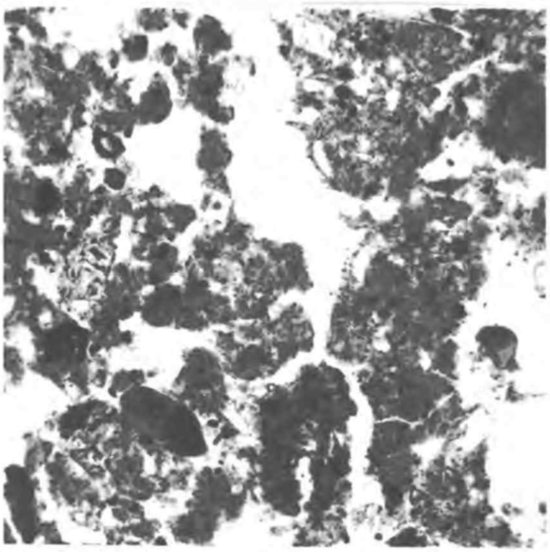


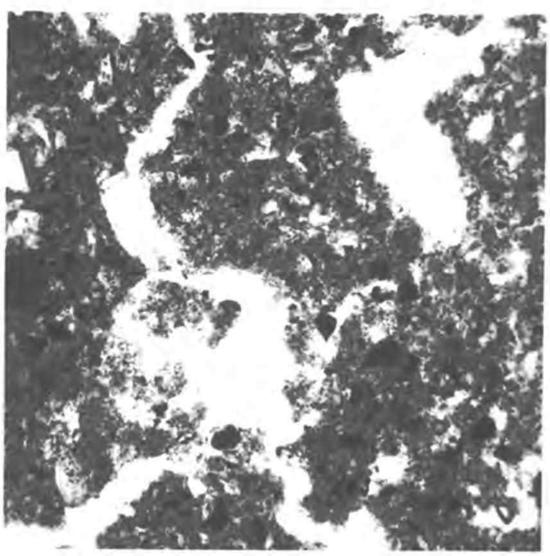
Fig. 9
Quillayute silt loam B_{21} 38-39"
50μ

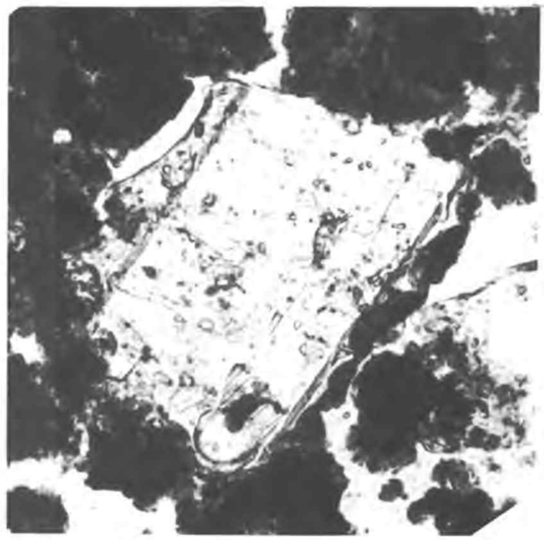
1. Isotropic, spheroidal blobs, containing silt 2. Tubular pores 3. Matrix

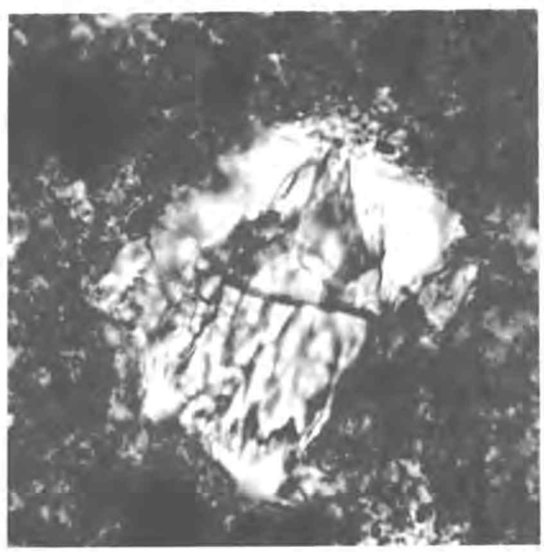












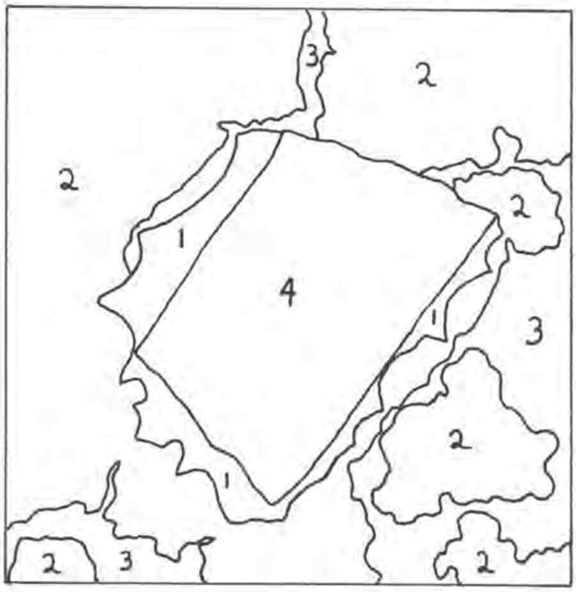


Fig. 10
Quillayute silt loam A_{12} 16-17"
100 μ

1. Volcanic glass 2. Dark brown granular aggregates 3. Interstitial pores 4. Plagioclase crystal

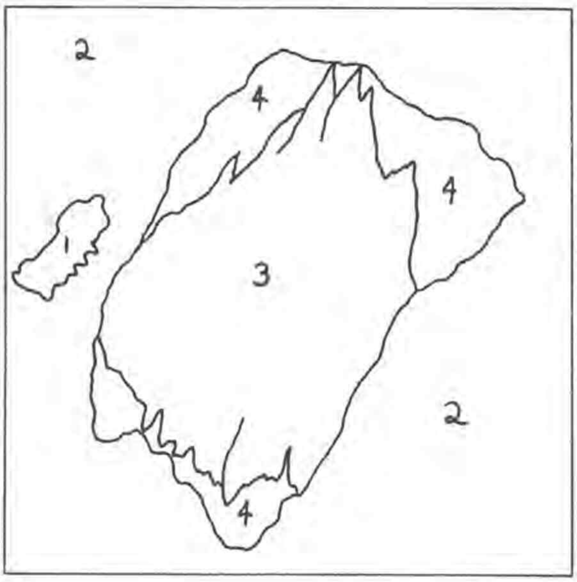


Fig. 11
Quillayute silt loam B_{21} 38-39"
25 μ

1. Grass opal 2. Matrix
3. Etched augite crystal
4. Void (?) delineating former grain shape

slightly oriented coatings of clay similar to that constituting the matrix are visible on some ped surfaces and in a few pores. These coatings contain fine silt and are indistinguishable from ped interiors with plane light.

Interpretation

Regardless of the scale at which this profile is observed, one is impressed by the ubiquitous evidence of mixing. As soon as pores are vacated they are filled with the well aggregated material characteristic of all but the lowest horizons. It seems more than likely that only the most recently filled pores are identifiable as such, and that any given aggregate must have experienced innumerable cycles of pore formation and filling. Whether plant or animal agents are more important in forming such pores is difficult to determine and probably beside the point.

Continuous physical disruption on both a macro- and micro- scale is very likely the principal factor responsible for the absence of sharply contrasting horizons in this and similar soils in the vicinity.

If colloidal material is being actively removed from upper horizons, there is very little evidence of its concentration lower in the profile. Assuming that chemical weathering is taking place, therefore, the products are either completely removed or accumulate in some form not readily observable. Considering the magnitude of precipitation and its concentration during cooler weather, there is good reason to suppose that a significant amount of material could be removed from the profile both in solution and suspension.

Since pyroxenes are the only mineral species present which show positive indications of significant weathering in place, one might conclude that this profile is too immature to possess colloidal accumulations of either a primary or secondary nature. Pyroxenes etched in a similar manner, but to a greater degree, have been noticed by many observers both in soil profiles and sedimentary deposits (11, p. 73; 1, p. 970).

Most of the monomineralic sand grains, e. g. quartz, plagioclase, augite and hornblende, occurring in this profile are listed in descriptions of coarse grained intrusives of the Coast Range and might logically derive from those formations. Glass sheathed plagioclase phenocrysts, however, though few in number cannot be so easily explained. Similar phenocrysts though larger and more plentiful, were noted in both alluvial soils studied from the Willamette Valley. Since the grains from all three of these locations bear a striking resemblance to those commonly found in pumice deposits of central Oregon, there is little doubt that they originally derived from a volcanic ash shower. Which of the many known eruptions was responsible for these enigmatic crystals and whether or not they were deposited directly from the air or not, will doubtless remain open to question for some time. Considering the proximity of the sites under consideration to Crater Lake, and the tremendous volume of pumiceous ejecta produced by that vent relative to others at equivalent distance, it seems reasonable to postulate that the ejecta under consideration is the distal portion of the great Mazama pumice fall. Direct proof of this hypothesis is lacking at present. Regardless of the source, if the grains in question have a common origin they could serve as a valuable stratigraphic indicator.

Allophane or halloysite come closest to matching the optical characteristics of the nearly isotropic, very pale yellow material. Globular shape of the aggregates suggests that allophane predominates. Montmorillonite approaches the optical properties of the more highly birefringent, bright yellow particles and the clay occurring in shale fragments. Although this type of evidence is far from positive, it indicates a strong possibility that clays inherited from parent material are altering in response to environmental conditions.

Description of Thin Sections

Jory silty clay loam A_{12} 11-12"

Low power. Angular silt grains occupy a dark reddish brown, clayey matrix. Approximately half the section consists of irregular, coarse sand-size pores. Angular sand-size particles constitute about 10% of the solid material. Approximately 5% of the pores possess laminated, discontinuous red clay skins.

Medium power. Sand-size constituents include such secondary minerals as cliachite, gibbsite, goethite and limonite; spherical iron oxide concentrations (shot); charcoal fragments; glass-shrouded, zoned, plagioclase phenocrysts; and glass shards. Clay skins are moderately well oriented and differ from those in lower horizons only in being thinner and less extensive. Many pores have margins which are darker and less porous than the surrounding aggregated material.

High power. Angular silt grains are predominantly feldspars and quartz. Secondary iron and aluminum compounds identified in the sand fraction are present also. The reddish brown matrix material appears to consist primarily of equidimentional coarse clay and fine silt-size particles in a pale yellow, isotropic matrix.

Jory silty clay loam A_3 19-20"

Low power. Moderately dense, fine and very fine, subangular blocky peds of dark reddish brown clay are studded with angular silt, sand-size clay fragments, iron concentrations and bauxitic secondary minerals. Irregular, interpedal pores make up 30% of the section.

Medium power. Many pores are coated with, and some almost filled with, silt and very fine sand-size spheroidal blobs of isotropic, reddish yellow material of very low relief. A very few pores have thin coats of moderately oriented, unlaminated, yellowish red clay. The only laminated clay occurs as fragments of broken clay skins. Those spheroidal blobs which contain a high percentage of fine silt-size matrix material are nearly as dark as the general matrix and are indistinguishable from it when they become closely packed.

High power. In some pores the pale yellowish red material is itself coated with clear, isotropic, pale green colloform material of moderate positive relief.

Jory silty clay loam B_{21} 27-28"

Low power. Angular silt and sand grains are embedded in a dense matrix of massive red clay. Optically oriented, laminated clay is present only as fragments of disrupted thick coatings similar to those present in lower horizons. A few pores have thin coats of moderately oriented, unlaminated, yellowish red clay. Most of these coatings have blobs of the paler, isotropic material on their inner walls. Irregular pores make up only 15-20% of the peds.

Medium power. Ped surfaces and larger pores are discontinuously coated with silt and sand-size blobs of colloform, reddish yellow material similar to that described in the matrix of the A horizons. Approximately 5% of the pores contain discontinuous coatings of moderately oriented (not laminated) red clay.

High power. The matrix consists of red, fine silt and clay-size particles embedded in yellowish red isotropic material similar to that described in upper horizons.

Jory silty clay loam B_{23} 43-44"

Low power. Dense, fine, angular to subangular, blocky peds of massive red clay are studded with angular silt and sand. Sand grains consist chiefly of secondary iron and aluminum oxides. Approximately half of the pores are filled or nearly filled with yellowish red, laminated, highly oriented clay displaying low birefringence. Most of these thick clay skins show signs of physical disruption and fragments of laminated oriented clay occur within the matrix. Pore space within peds is less than 10%. Many pores are partially filled with sand and silt-size aggregates of matrix-like material, some of which are coated with oriented clay.

Medium power. Thick laminated clay accumulations are traversed by cracks, many of which contain unlaminated, highly oriented clay skins displaying slightly brighter interference colors than those which are laminated. Some pores are coated only with unlaminated clay.

High power. Laminations in clay skins are delineated by concentrations of clay-size blobs of dark red, apparently isotropic material. These particles are present in unlaminated clay skins, but are not concentrated into definite bands. Matrix material consists of very fine silt-size particles set in a reddish yellow, isotropic substance, similar to that which occurs as blobs within many pores. Thin, colloform, coatings of clear isotropic material of low relief constitute the most recent accumulation in many pores.

Jory silty clay loam B_{24} 50-51"

This horizon appears to be a mixture of components from A and B horizons. Granular, dark reddish brown aggregates are thoroughly stirred up with dense red matrix and disrupted red clay skins. Since the mixture is much more porous than horizons immediately above, there is a distinct possibility that it represents the contents of a root channel or some other atypical situation.

Fig. 12
Jory silty clay loam A_3 19-20"
50 μ

1. Translucent, reddish yellow, isotropic colloform material
2. Dark reddish brown matrix
3. Pore

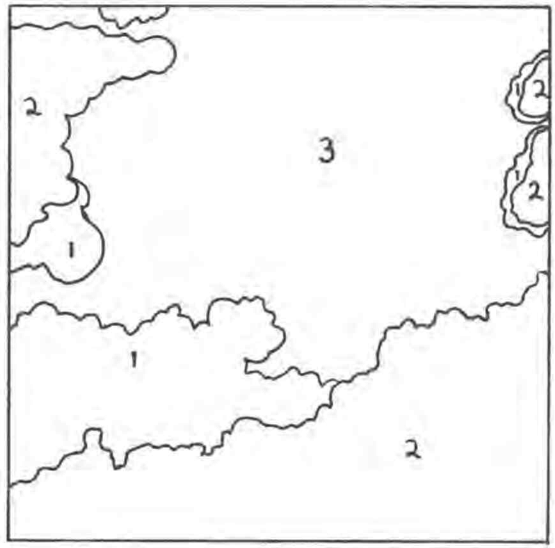


Fig. 13
Jory silty clay loam A_3 19-20"
50 μ

1. Silt grain 2. Pores
3. Fragment of laminated clay skin similar to those still intact in the B horizons
4. Dark reddish brown matrix

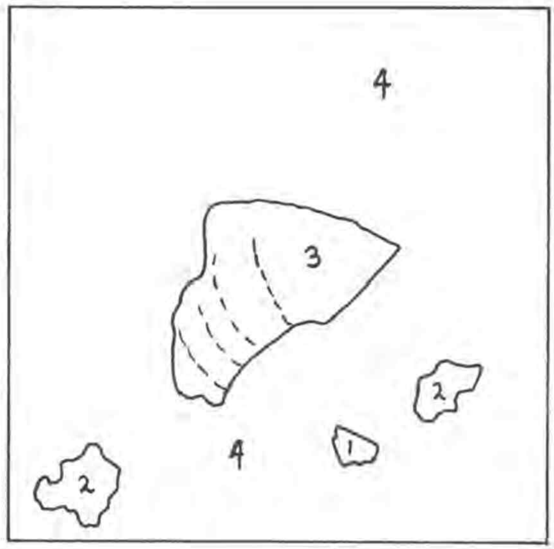
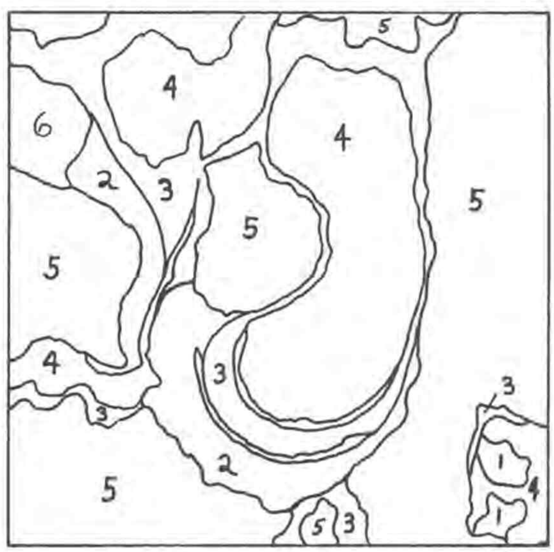
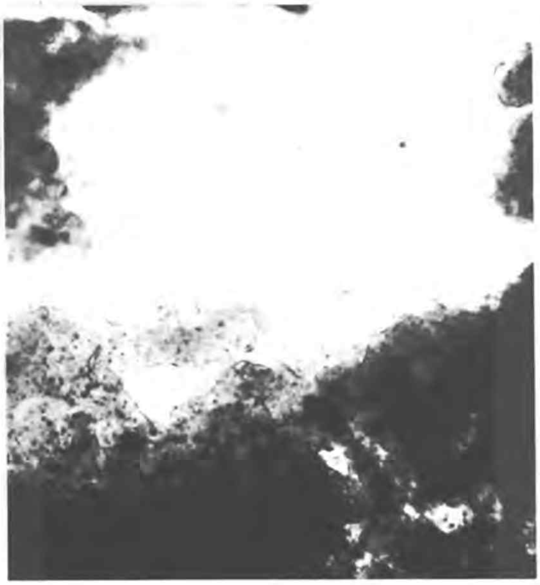
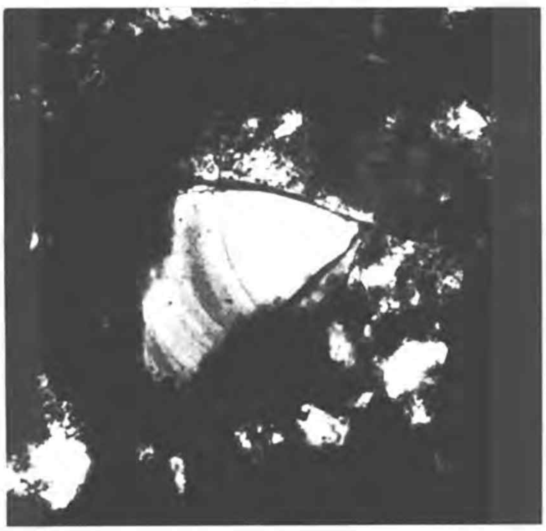


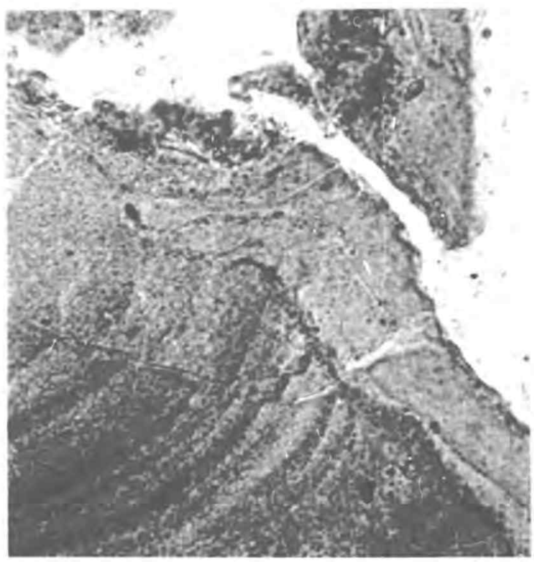
Fig. 14
Jory silty clay loam B_{22} 35-36"
60 μ

1. Isotropic, colloform blobs containing silt grains
2. Laminated, optically oriented clay accumulations
3. Unlaminated, optically oriented clay accumulations
4. Pores 5. Red, clayey matrix
6. Black manganese-dioxide concentration









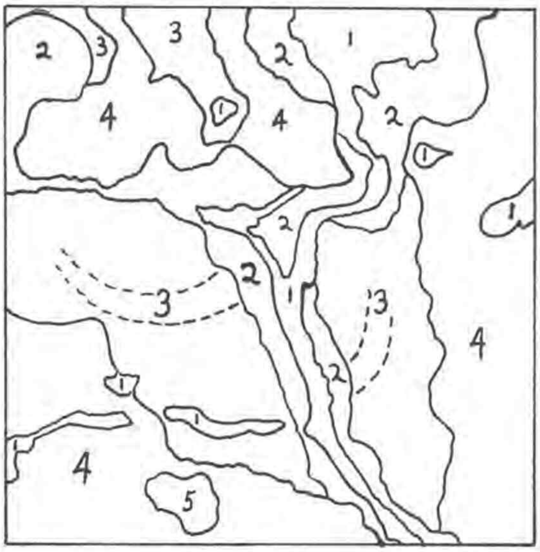


Fig. 15
Jory silty clay loam B_{23} 43-44"
60 μ

1. Pores 2. Oriented, unlaminated clay 3. Oriented, laminated clay accumulations 4. Red, clayey matrix 5. Cliachite

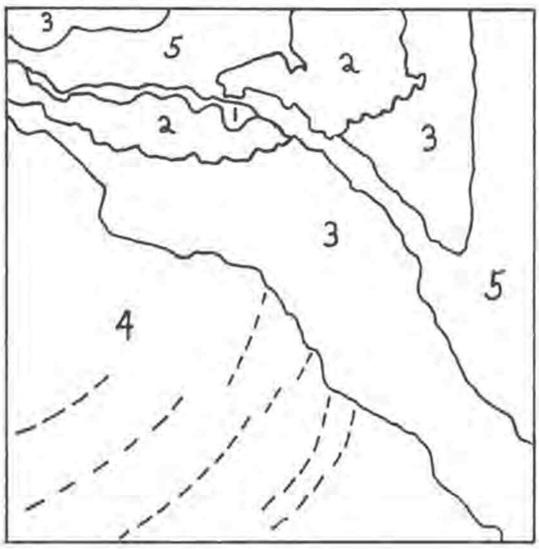


Fig. 16
Jory silty clay loam B_{23} 43-44"
10 μ

Enlarged central portion of Fig. 15
1. Clear, colloform, isotropic material 2. Silt size particles in isotropic matrix 3. Oriented, unlaminated clay 4. Oriented, laminated clay 5. Pore space

Interpretation

Sand-size grains consist primarily of secondary minerals common to the local ferruginous bauxite (15, p. 79). Recognizable constituents of weathered basalt are rare or lacking. An obvious inference would be that the local ferruginous bauxite is a more important contributor to this soil than basalt *per se*.

Angular silt grains are common throughout the profile, although decreasing in quantity with depth. Angularity, freshness and size range suggest the possibility of loess. A few grains of quartz and feldspar are positively identifiable but fine silt components, because of small size and matrix opacity, are almost impossible to identify. Even the relative abundance of this fraction is difficult to estimate except in sections less than 20 microns thick. All silt grains taken together would make up a layer approximately one foot thick. There are rare, sand-size, euhedral grains of zoned plagioclase and hypersthene, which resemble those more easily found in alluvial soils of Willamette Valley.

A certain amount of mixing is characteristic of the whole profile, but the upper and lowermost samples are noteworthy. A horizons contain at least 5 to 10% of materials identical to those presently constituting B horizons. Unaltered pieces of material resembling B matrix do occur, but discrete sand-size particles of laminated, optically oriented clay skins are far more striking in appearance. The deepest sample taken contains a large proportion of material somewhat resembling the present A horizons.

Occurrence of cracked and broken, thick, laminated, highly oriented clay skins indicate a period of relative physical stability followed by one of considerable instability. The presence of coatings of unlaminated, moderately well oriented clay similar to that in the laminated coatings, but deposited within cracks in the older clay skins or in entirely different pores suggest a more recent period of stability. Since the unlaminated skins are thinner and less widespread, they probably indicate a shorter period of stability. Colloform coatings of isotropic material occur within the other types, probably representing the most recent alteration of pedalogical environment; perhaps deposition of thin superficial volcanic ash, or loess, or both.

At present, silt and sand-size blobs of matrix-like material, appear to be moving down larger pores, especially in upper horizons. Except for differences in color, this highly aggregated material closely resembles that noted in pores of the Quillayute and Astoria profiles.

Micromorphological similarities between these two profiles and the upper horizons of the Jory are sufficiently pronounced to suggest that all three are presently dominated by similar developmental processes. Recent surficial deposits, or a change in climate (10, p. 115), or both, may be responsible for this postulated shift in character of the upper Jory profile. A more complete knowledge of the areal distribution of this and related soils in western Oregon would clarify the relative importance of these two factors.

Optical properties of clay fraction in the matrix material suggest allophane or halloysite with varying amounts of iron oxides. Oriented clay skins could consist of a chlorite compound or perhaps an iron-stained kaolinitic clay.

Variable sand-size grains of secondary minerals common to the local ferruginous bauxite deposits (15, p. 79)(gibbsite, cliachite, goethite, and limonite) are common. Recognizable particles of weathered basalt are extremely rare. Part of the present soil, at this site, appears to derive from this laterite deposit or associated highly weathered material. Future field work may reveal just how closely this soil series is associated with deposits of ferruginous bauxite.

Description of Thin Sections

Woodburn silt loam A_p 4-5"

The A_p differs from the A_3 horizon in having higher organic matter content (both decayed and undecayed), somewhat larger shot, more granular structure, higher porosity, lower clay content, no clay or wilt coats, and very slight tendency for ped and pore margins to be darker brown than ped interiors. Grains forming the walls of pores are quite clean. Pyroclastic plagioclase is present but in smaller grains and amounts than either of the two horizons immediately below.

Woodburn silt loam A_3 10-11"

Low power. Coarse and fine, angular silt grains, primarily of feldspar and quartz are packed in moderately dense fashion in a massive matrix of very fine silt, clay, and organic matter. Sand grains of andesitic plagioclase and hypersthene, some partially coated with glass, are present but in smaller quantities than in the next lower horizon. Sand-size, subrounded to rounded shot, with sharp boundaries constitute approximately 5% of the horizon. Irregular very fine tubular pores are common and provide the majority of the pore space of this horizon.

Medium power. Many pores are bounded, especially on their lower sides, by thin, brown to yellow brown coatings which display weak to moderate optical orientation. Larger pores usually have thicker coatings, which are not laminated in an orderly fashion, but consist of thin lenses of variable caly and silt content and optical orientation. A very few pores contain thin coatings of oriented clay similar to those in the B_1 horizon.

High power. Red matrix material of shot shows crystalline continuity over small portions (silt-size areas) with optical orientation referred to surfaces of silt grains within the shot. Some shot have an irregular peripheral zone which is less red and less crystalline than the central portion. Clay skins consist of clay plus fine silt grains, many of which are micaceous. A sufficient proportion of these fine mica flakes have their long axes parallel to the pore surface to give the entire coating the appearance of weak optical orientation.

Woodburn silt loam B_1 18-19"

Low power. Angular silt grains of quartz and feldspar occupy a rather dense, yellowish brown matrix of clay particles, very fine silt, and organic matter. Tubular pores and reddish brown, sand-size iron oxide concretions are common. Approximately half of the tubular pores and cracks have thin skins of well oriented yellowish brown clay, many of which are thickened on the lower side of pores. A few fill the pore which they occupy. All of the iron oxide concretions appear to contain silt equal in amount to a similar volume of matrix material. They vary in size, shape, color, sharpness of boundary and degree of concentration of iron and manganese oxides. Colors range from dark reddish brown to reddish brown, boundaries from sharp to clear, and shape from rounded to subrounded. Smaller shot tend to be darker, rounder, and have more distinct boundaries. Only the thickest clay skins are distinctly laminated. Sand and silt-size fragments of charred wood are noticeable but not abundant. A few medium and coarse sand-size fragments of zoned plagioclase crystals are conspicuous by their large size (largest mineral particles in the horizon) and frequent association with coatings of volcanic glass. A very few hypersthene crystals of similar size accompany the plagioclase.

Medium power. Laminated clay skins frequently contain layers of weakly oriented silty clay or unoriented silty matrix material. Where silty layers are innermost in pores, the inner grains are exceptionally clean. The matrix appears darker brown adjacent to pores and cracks lacking clay skins. Sand and silt-size fragments of clay skins are a conspicuous part of the silty material. Some of these fragments appear only slightly disturbed, others are completely shattered.

High power. Darker pore walls and ped margins contain less clay than the matrix, but display weak optical orientation. Silt grains projecting from these darker areas are devoid of visible coatings. A few clay skins have very thin ($<10\mu$) discontinuous coatings of pale purple, isotropic material on inner surfaces.

Woodburn silt loam B_{31} 35-36"

Low power. Medium sized, angular to subangular blocks of moderately dense silt, clay and organic matter are riddled with many, fine tubular pores .5 to .25 mm. Approximately half the pores and cracks between peds have coatings of optically oriented yellowish brown to brownish yellow clay. Zones of iron and manganese oxide concentration are common and usually associated with pores. They range from very dense, nearly opaque, very dark brown, subrounded shot, with sharp boundaries, to diffusely stained areas which are noticeably darker than the silt.

Medium power. A considerable portion of the fine silt fraction consists of opaque and nearly opaque particles, which are primarily responsible for the dark brown color of this horizon. Thicker clay skins are laminated but individual layers are thin ($\sim 10\mu$) and boundaries between them usually gradual. Color of oriented clay varies from brownish yellow to dark brown. Darker bands result from concentration of clay-size particles of reddish brown isotropic material.

High power. Clean, angular, coarse and fine silt grains are set in a moderately dense matrix of much finer silt and clay-size particles. The dirty nature of the matrix makes any but the roughest approximation of constituents impossible. Quartz and feldspar, in approximately equal proportions appear to dominate the coarse silt with lesser amounts of muscovite. Magnetite is a small but significant part of the fine silt. A wide variety of rock types, from basaltic to granitic, are represented in all size fractions but are most conspicuous as very fine sand.

Clay forming oriented skins exhibits a small 2V ($\sim 15^{\circ}$), refractive index from 1.56 to 1.60, and interference colors of second order green and yellow. Thin discontinuous films of pale purple, isotropic material are somewhat more plentiful than in higher B horizons.

Woodburn silt loam C 70-71"

Low power. Apparently massive silt occurs in two distinct textures. In one, angular to subangular coarse silt predominates over interstitial fine silt and clay. The other lacks coarse silt almost entirely, consisting merely of fine silt and clay particles densely packed without noticeable preferred orientation. Boundaries between these two materials vary from clear to diffuse and no orderly arrangement was observed in thin-section. Fine tubular pores and finer interstitial ones, many of which are half full of oriented clay occur much more frequently in the coarser than in the finer material. Clay skins in horizontal pores are conspicuously thicker on the bottom and frequently display striking lamination and obvious pleochroism where thickest. Many of the larger pores have dirty, moderately oriented clay skins inside the purer, strongly oriented ones, and which are separated from them by an abrupt boundary. Very dark brown to black (manganese dioxide?) stains occur interstitially in matrix material, on and around clay skins, and occasionally as discrete, shot-like concentrations.

Medium power. The coarse silt portion contains a great deal of opaque silt size particles which give the whole a dirty appearance. Interstitial pores between coarse silt grains are commonly lined with thin moderately oriented clay skins. In the fine silt portion both interstitial pores and their accompanying clay skins are lacking. Clay in this portion occurs as randomly oriented fine silt-size flakes. At least half of the opaque particles are magnetite and rock fragments. The rest is probably organic material of uncertain nature.

High power. Mineral grains, without exception, appear very fresh. Rock fragments however, display varying degrees of oxidation, often sufficient to obscure the nature of the rock completely. Very thin ($\sim 5\mu$) skins of moderately oriented clay occur on some surfaces of some grains but most noticeably on flakes of mica. Many interstitial voids as well as clay skins are very thinly coated with a clear, isotropic, pale purple substance which has low, negative relief. Pollen grains, though insignificant in volume, are widespread in matrix material.

Maximum thickness of both iron-manganese oxide and pale purple, isotropic films (the latter often coat the former) occurs in the 64 to 65 inch section.

Fig. 17
Woodburn silt loam Ap 3-4"
70 μ

1. Pores 2. Iron oxide concentration 3. Tightly packed angular silt grains, organic matter, clay and grass opal.

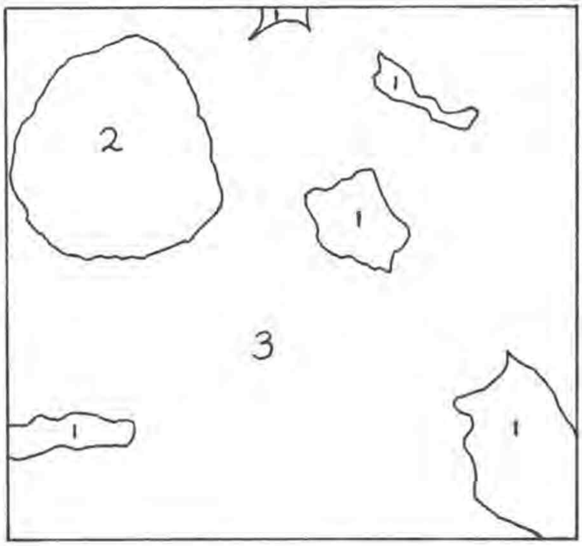


Fig. 18
Woodburn silt loam B_2 23-42"
70 μ

1. Isotropic material
2. Tubular pores 3. Laminated, oriented clay 4. Dense matrix of silt, clay and organic matter 5. Silt and organic matter partly filling a tubular pore

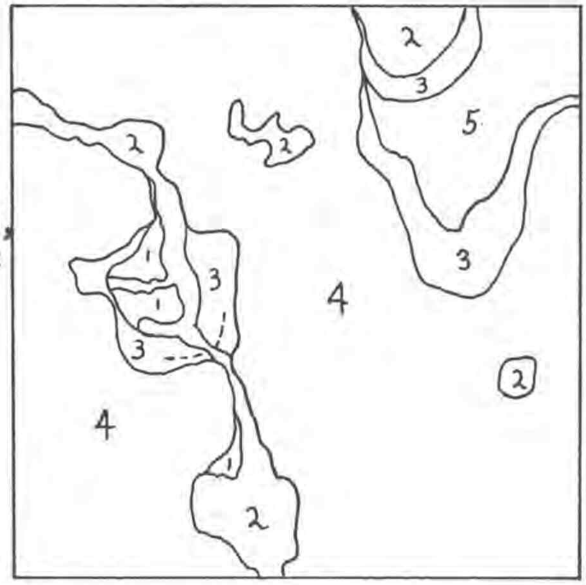
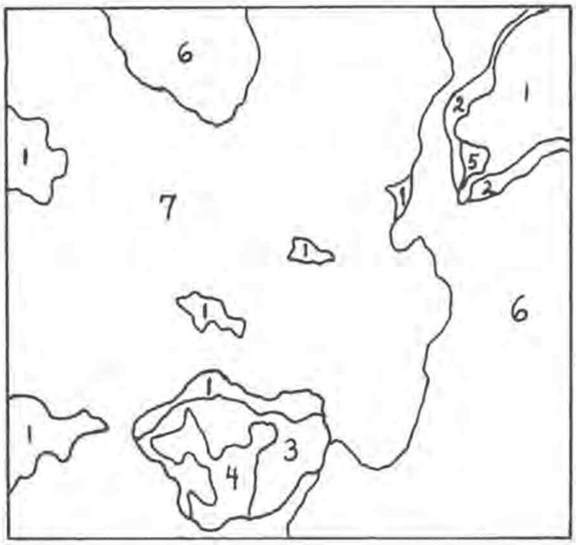
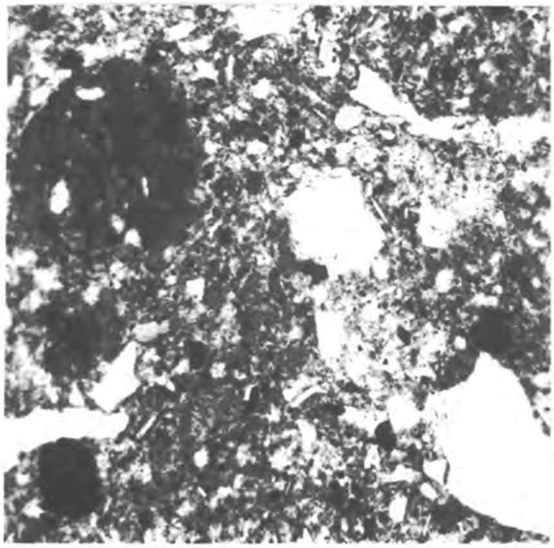
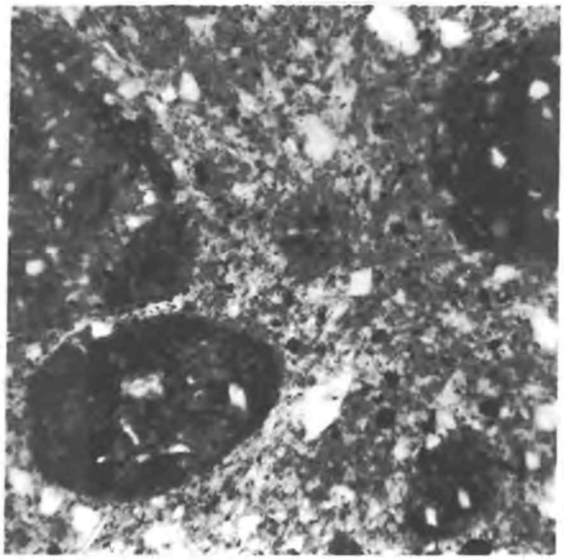


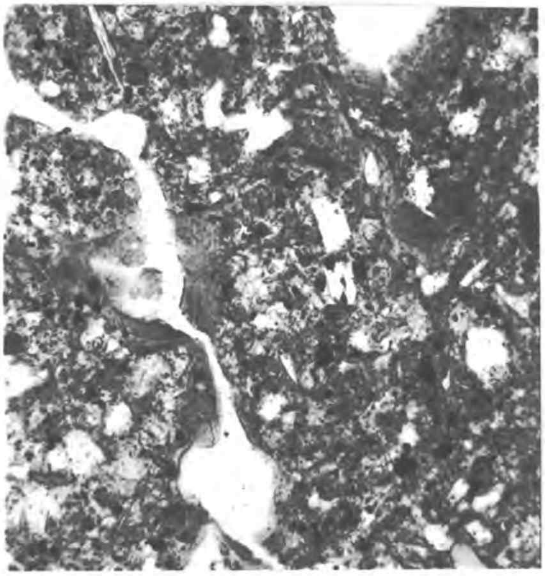
Fig. 19
Woodburn silt loam C 70-71"
100 μ

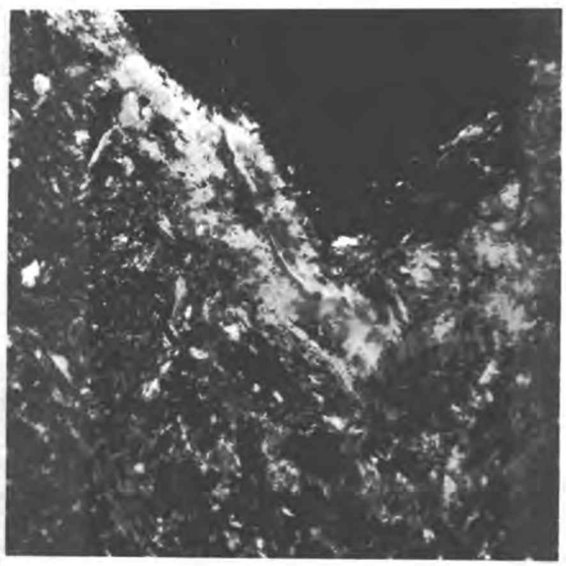
1. Pores 2. Oriented clay skins containing fine silt
3. Oriented, laminated clay
4. Manganese oxide 5. Clear, isotropic material 6. Tightly packed, fine silty matrix.
7. Porous, coarse silty matrix

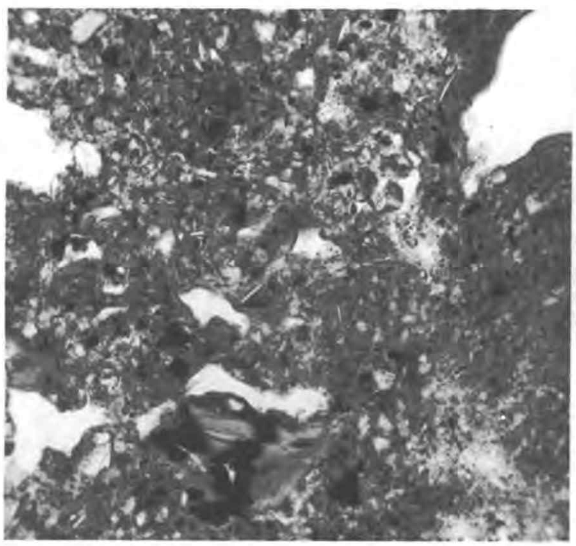












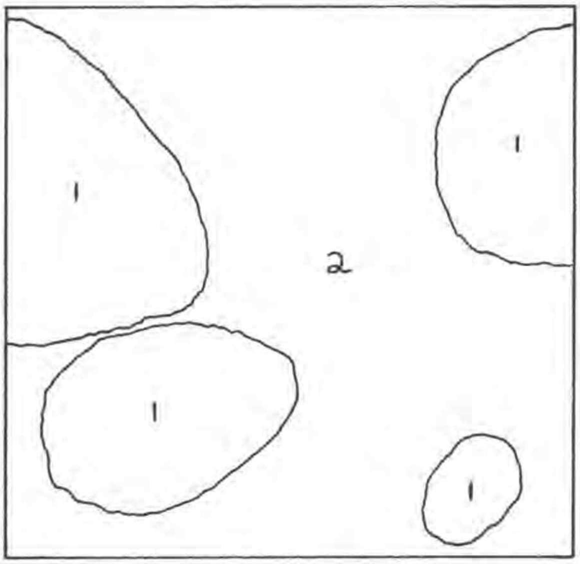


Fig. 20
Woodburn silt loam A_3 11-12"
100μ

1. Rounded iron oxide concentrations 2. Matrix of angular silt and organic matter

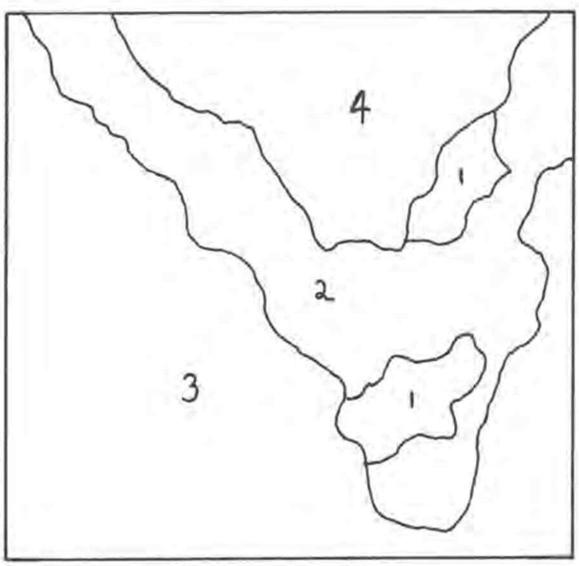


Fig. 21 polarizers crossed
Woodburn silt loam B_{32} 49-50"
100μ

1. Oriented clay at position of extinction 2. Oriented laminated clay 3. Matrix of silt and clay 4. Pore

Interpretation

Soils exhibiting marked similarities, both microscopic and macroscopic, with this Woodburn profile have been described in central New York state by Frei and Cline (7, p. 343) as intergrades between Brown Podzolic and Gray-Brown Podzolic soils. They interpret the evidence presented as indicating that the Brown Podzolic profile was developing at the expense of a pre-existing Gray-Brown Podzolic profile as bases were being removed. A similar sequence of horizons, in Hosmer silt loam from southern Illinois, is interpreted (9, p. 65) as indicating the development of a Red-Yellow Podzolic profile on a previous Gray-Brown Podzolic soil. Development and distribution of laminated clay skins in B horizons, interfingering of material from lower A horizons with that of upper B, and nature and distribution of sesquioxide concentrations all point to significant agreement in sequence and degree of expression of the major horizons. If Woodburn is a bisequal soil, as this parallel would lead one to suspect, a search for profiles of different age on similar parent materials should clarify relationships between components of the bisequum.

Occurrence of iron- manganese oxide films and silt coats on illuvial, laminated, clay skins is strong evidence of environmental change, perhaps a rapid one, during development of the present profile. The sesquioxide coatings suggest a relatively recent deterioration of drainage. Such a shift in drainage could have resulted from a raised water table, clogged pores, or deepened profile resulting from addition of surficial deposits. Rather abrupt appearance of silt within the clay skins tends to point toward addition of surficial silt rather than some more gradual alteration, such as degradation of the upper horizons as a mechanism leading to migration of silt down the profile.

A possible sequence of events could have begun with profile development during initial entrenchment of the Willamette River. Filling of the channel with sediments on which present Chehalis and Newberg soils occur would have raised the water table allowing flood deposits to accumulate on the upper surface once more. Recent incision has lowered the river so that flood waters no longer reach the level of this particular Woodburn site.

If changes in river levels have been an important factor contributing to the bisequal profile postulated herein, one could expect considerable variation among these soils through the valley since vertical distance between the river and given terrace levels varies markedly within the valley. If climatic fluctuation is chiefly responsible, Woodburn profiles should be reasonably similar through the valley.

Large grain size and pumiceous envelopes indicate that the zoned plagioclase crystals noted in the upper horizons are of pyroclastic origin and not genetically related to the silts in which they are found. A brief petrographic examination of volcanic ash from the deposit described by Hansen (10, p. 84) from Lake Labish, revealed approximately equal amounts of sand-size pumiceous and crystalline material. Medium to coarse sand-size plagioclase (andesine-oligoclase) showing oscillatory zoning is the dominant mineral species. Hypersthene, augite, green hornblende and magnetite combined account for less than 20% of the crystalline fraction. Most grains are enveloped in glass to some extent. Petrographic features of minerals in this ash are in such close agreement with Williams' description of the "Mazama" pumice deposit at Wickiup damsite (22, p. 103) that the two can reasonably be attributed to the same eruption. At present there is no reason to doubt that the pyroclastic plagioclase noted in the five western Oregon soils dealt with in this study all derives from this same eruption. Since the "Mazama" pumice eruption has been dated at 7,600 years B.P. (23) some light is shed on the approximate age of soils which it mantles. The greatest concentration of pyroclastic plagioclase occurs in the B_1 horizon of this Woodburn profile, indicating that perhaps twelve to eighteen inches of silt have accumulated on this site since deposition of the ash.

No pumice was observed in thin sections of the Woodburn soil, suggesting that at least the glassy fraction of the ash deposit has been altered beyond recognition. What effect the weathering of this pumice deposit has had on the present profile is difficult to assess. The most recent, lightest colored clay skins may derive from the weathered glass. There is also a distinct possibility that the very thin pale purple, isotropic coatings are gel from dissolved glass, since the two have approximately the same index of refraction.

Neither the known ash deposit (approximately two inches thick) nor postulated surficial silt, which would show considerable variation in depth from place to place, is necessarily a controlling factor in development of a bisequal profile. As long as the magnitude of these additions was not great enough to alter qualitatively the processes dominating development of the upper sequence of horizons, the net effect was probably merely a change in rate.

Description of Thin Sections

Dayton silt loam Ap 4-5"

Low power. Interiors of fine subangular blocky peds consist of densely packed angular silt which is studded with occasional, dense, irregular, dark reddish brown iron oxide concentrations and traversed by common grass roots and by less common sand-size pores. Many pores are partially clogged with dense, spheroidal aggregates which are similar in composition to the horizon as a whole. Darker iron oxide concentrations have reddish brown halos.

Medium power. Pore walls are generally darker than the matrix, apparently due to higher content of organic matter. Interstitial porosity accounts for approximately one third of the pore space in this horizon.

High power. Matrix consists of angular silt grains, silt-size particles of organic matter, plant opal (~2%), pollen grains, and clay. Very rare, corroded, sand-size pumice and plagioclase grains occur. Silt-size mica flakes account for approximately 3-5% of the horizon.

Dayton silt loam A_{2g} 13-14"

Low power. Clean, angular, coarse and fine silt in a matrix of very fine silt and clay is studded with a diverse array of iron-manganese concentrations which vary in size from sand to gravel, in shape from spherical to amoeboid, and in distinctness of boundary from sharp to diffuse. Smaller concentrations tend to be more regularly rounded, more highly concentrated, and have more distinct boundaries. The larger ones range from dense, semi-opaque, shot-like concretions to diffuse, reddish brown stained blotches, which frequently contain opaque, very dark brown areas. In all cases, concentrations contain as much silt as an equal volume of the horizon in general. A small percentage of very fine sand grains are present and an even smaller amount of euhedral sand-size crystals of plagioclase, hypersthene and hornblende. These crystals often have clear, pumiceous glass still adhering to some surfaces.

Medium power. Most of the silt grains are quartz or feldspar, with muscovite and magnetite present, but in much smaller quantities. Smaller interstitial particles, between these clean, coarser grains, give the horizon a grayish brown color. This interstitial material consists of a wide variety of mineral and organic matter. Some recognizable elements are grassopal, pollen grains, glass shards, diatom tests, and sponge spicules. Pore walls frequently appear darker than the matrix in general.

High power. Darkened pore walls appear to result from denser packing of the fine silt matrix material and higher content of organic matter. Most of the clay occurs as interstitial aggregates of fine silt-size. Some pore walls have clear, thin, discontinuous, colloform coatings of pale purple opaline material displaying low negative relief. Interstitial pore space accounts for a third of the total porosity of this horizon.

Dayton silt loam B_{2g} 21-22"

Low power. Densely packed clay and angular silt is studded with dark reddish brown iron oxide concentrations. Irregular, fine tubular pores are common; interstitial pore space is nonexistant. Clay content appears higher at the top of the prism than elsewhere in the B horizon.

Medium power. Many pores are coated with poorly oriented, unlaminated, brownish yellow, colloform accumulations of clay which displays low positive relief and low second order interference colors. These coatings merge gradually into clay rich matrix material on their inner margins. Toward the pores they gradually merge with pale green material of low positive relief, the birefringence of which varies from very low to nil.

High power. Plant opal is present in the clay-rich prism margins as well as matrix material in general, but can be discerned only with difficulty. Ped margins bear a strong resemblance to those noted in the Lookout profile.

Dayton silt loam B_{2g} 30-31"

Low power. A homogenous mixture of angular, fine and coarse silt with clay particles and occasional very fine sand grains is studded with irregular, dark brown manganese and iron oxide concentrations and cut by random streaks of oriented clay particles. Larger concentrations are subrounded and some show vague concentric structure. Smaller ones appear fragmentary. Regardless of size, the majority of concentrations have sharp boundaries.

Medium power. Many concentrations are partially surrounded by tangential streaks of stress-oriented clay particles. Similar streaks sometimes separate coarser silty, less clayey material adjacent to cracks from fine silty, more clayey material which makes up the greater part of the prisms. Irregular, thick to thin, colloform coatings of pale green isotropic material of moderate to low positive relief covers most ped surfaces. These coatings merge gradually with the clay rich matrix material. Highly porous accumulations of angular fine silt, plant opal, and organic particles occur discontinuously on ped faces. Vertical faces of major prisms are darker and richer in silt and organic matter than ped interiors. Plant opal and spheroidal blobs of very pale green, isotropic material of low positive relief form a conspicuous fraction of these prism margins.

High power. Parallel alignment of silt-size mica flakes is an important factor contributing to the striking streaks of preferentially oriented material criss-crossing major peds. These oriented streaks are "stress cutans" as defined by Brewer (2, p. 286).

Dayton silt loam BC 38-39"

Low power. This horizon is essentially similar to that immediately above except for more common pores, many of which contain laminated coatings of moderately oriented, slightly pleochroic, brownish yellow clay which displays second order interference colors. Distorted clay skins and fragments thereof are more common than those which appear intact. Many clay skins in pores are either stained dark reddish brown or covered by silty accumulations. Opaque black blotches of manganese oxide are common.

Medium power. Many larger clay accumulations bounding peds contain less than 20% silt grains and plant opal and are only poorly oriented. Pores are commonly choked by clay accumulations similar to those described from the top of prisms.

High power. Vertical faces of major peds are commonly but sparsely sprinkled with sand-size aggregates of pale green isotropic material, silt grains and plant opal.

Dayton silt loam C 51-52"

Low power. Angular fine silt grains and clay flakes are slightly packed in random fashion. A few very fine tubular pores and irregular sand and silt-size very dark brown to black iron-manganese concentrations interrupt the otherwise homogenous material. Most pores are lined with laminations of moderately to strongly birefringent, optically oriented clay. Coatings are much thicker on the lower side of horizontal pores. Very thick skins of moderately oriented, pleochroic, (brownish yellow to yellowish brown) clay in vertical cracks are striking but rare. Boundaries of iron-manganese concentrations vary from diffuse to sharp and vary in manner of occurrence from laminar coatings to amoeboid splotches.

Medium power. A significant portion of the fine silt fraction consists of opaque particles, both mineral and organic, which give the deposit a dirty, grayish brown appearance. Coarse silt and fine sand occurs in discrete zones or areas where it constitutes as much as 30% of the total deposit. Boundaries between coarse and finer materials range from sharp to diffuse and do not favor any particular orientation. Streaks of shear-oriented clay particles are absent. Grains in coarser textured zones are coated with a thin (10 to 30μ) layer of pale purple, isotropic material of moderate negative relief. Larger manganese oxide stains are associated with sand-size colloform blobs of this material.

High power. Small but significant quantities of grass opal, diatom tests, sponge spicules, and pollen grains are scattered throughout the matrix. Fine mica flakes are difficult to distinguish from small fragments of oriented clay: both are present and in similar amounts. Organic matter is more plentiful than in B horizons. Pale green, colloform coatings on clay skins are thicker than in horizons above.

Fig. 22
Dayton silt loam A_{2g} 13-14"
90μ

1. Volcanic glass 2. Plagioclase crystal 3. Aggregated silt, clay and organic matter

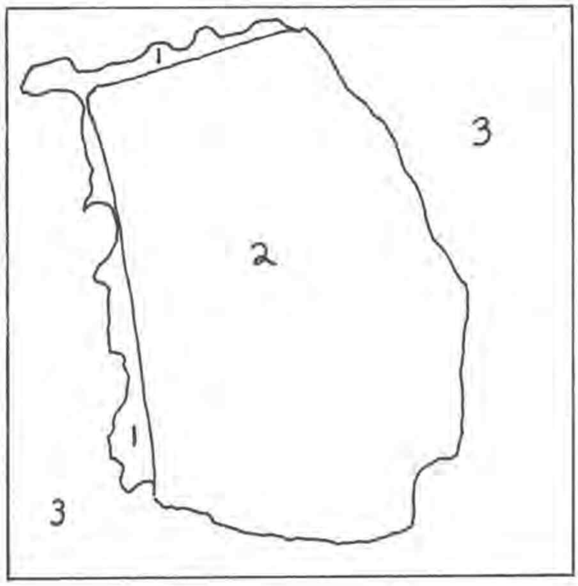


Fig. 23
Dayton silt loam A_{2g} 13-14"
70μ

1. Darkened pore wall 2. Iron oxide concentration 3. Ground mass of silt, clay, organic matter and plant opal 4. Tubular pore

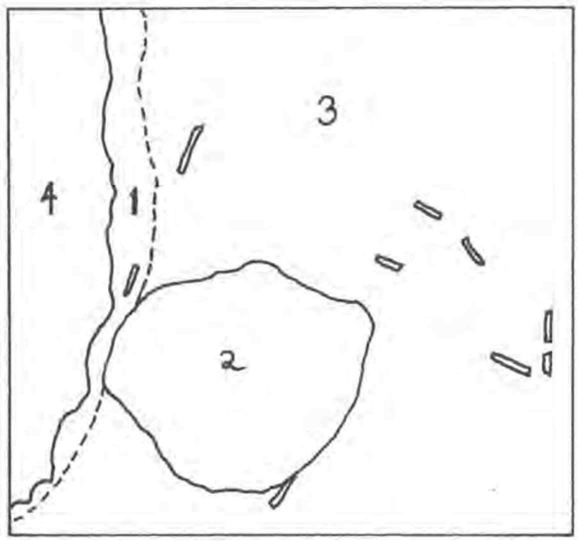
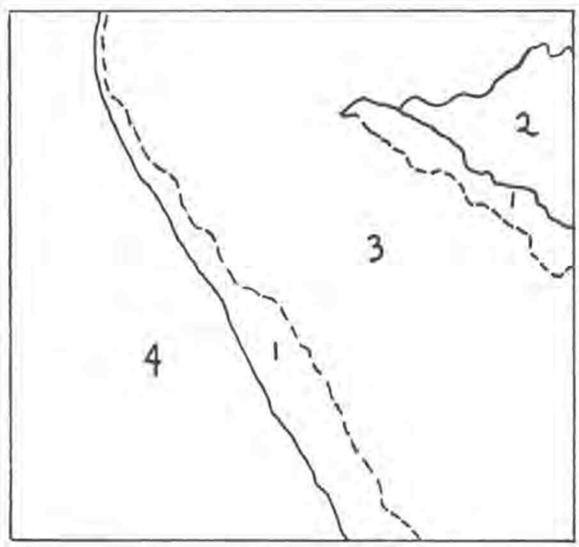
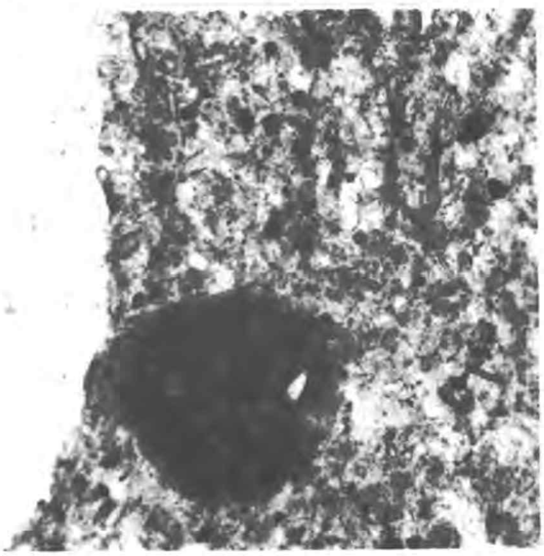
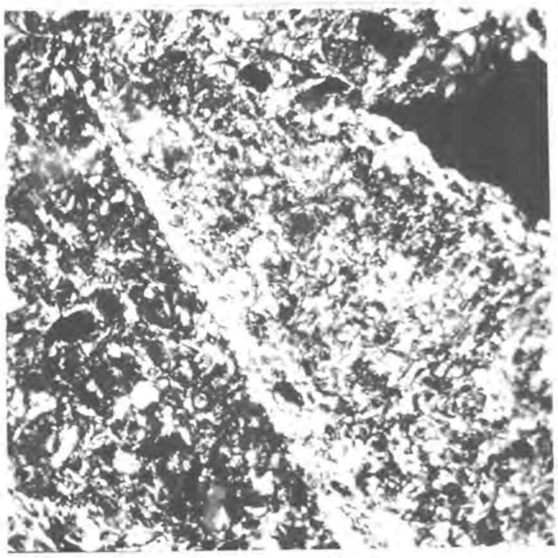


Fig. 24 polarizers crossed
Dayton silt loam B_{2g} 30-31"
70μ

1. Sheared oriented clay and silt showing gradual decrease in degree of orientation with increasing distance from the smeared face. The slickensides referred to in the profile description are of this type. 2. Pore 3. Clay rich, fine silty matrix 4. Clay poor, coarse silty matrix







Interpretation

In a study of claypan development in Dayton soils, Nikiforoff and Drosdoff (16, p. 61) concluded that the high clay concentration of the claypan resulted from weathering, in place of mineral grains composing that horizon rather than from illuvial accumulation of clay from overlying horizons. Evidence offered by thin sections substantiates their interpretation.

Most of the clay in the upper B horizon occurs as minute, randomly oriented flakes in the matrix. That which displays preferred orientation is undoubtedly due to shear stresses generated by shrinking and swelling. The percentage of clay present as laminated, optically oriented coatings increases with depth. Many of these structures are physically distorted, coated with iron-manganese oxide accumulations or covered with transported silt. The most obvious implication is that fluidal clay skins predate the development of the present profile.

Since pyroclastic plagioclase is concentrated in the A_2 horizon, there is a distinct possibility that a portion of the present A horizons has formed in a relatively recent surficial deposit. Silt-covered clay skins lend support to such a postulate. Iron-manganese oxide accumulations on clay skins indicates relatively recent deterioration in drainage conditions.

Except for differences in ped size and skeletal elements, B horizons of Dayton have marked similarities with analogous horizons in the Lookout profile. The association of stress-oriented clay within peds and colloform coatings of variable crystallinity on ped and pore surfaces is a strong indication that similar processes dominated development of B horizons in these two soils.

Although rainfall at present is sufficiently high (40") in the vicinity of this Dayton site to discourage pedological comparisons with soils of semi-arid regions, two mitigating considerations must be borne in mind.

Extremely low porosity of the Dayton B horizons results in very low water holding capacity. Leaching of the B horizon is limited to whatever water is able to filter down the interprism cracks before swelling of prisms has sealed them off. The effective precipitation for the B horizons is therefore only a small fraction of that which falls on the surface.

There is also a distinct possibility that major development of the present B horizons occurred during that warmer, dryer period between 4000 and 8000 years ago referred to by Hansen (10, p. 114). If the pyroclastic plagioclase of the A_2 horizon is derived from the last eruption of Mt. Mazama, both that volcanic deposit and the silt which appears to overlie it may well postdate development of the present B horizon.

Common occurrence of streaks of oriented clay, which owe their origin to shear stresses (2, p. 286) within prisms, is mute evidence that shrinkage and swelling contribute much to the present character of the B horizons. Swelling which follows autumn rains could be expected to exert considerable lateral pressures, especially since silt and organic matter from A horizons partially fill the cracks before they are completely closed. Assuming that weathering of silt grains in these horizons is significant during summer months, the resultant weathering products might be extruded as swelling pressure increased. Colloform coatings which occur on rounded prism tops and in horizontal cracks could well originate in this manner. Rounded prism tops themselves probably result from vertical extrusion of more clayey prism centers; since little or no room is available for lateral or downward expansion.

Description of Thin Sections

Walla Walla silt loam A $_{1pm}$ $7\frac{1}{2}$-8"

Low power. Dark brown, medium to fine plates are composed of moderately to tightly packed, angular silt and very fine sand grains which are coated with organic matter, fine silt and clay. Coarser sand particles are chiefly rock fragments, most of which are plagioclase phenocrysts shrouded in partially devitrified pumice. Tubular pores are uncommon and pore space within plates is principally interstitial between skeletal grains. A tightly packed layer, with a sharp, smooth, horizontal upper boundary is present.

Medium power. Devitrified pumice surrounding plagioclase phenocrysts is stained by or aggregated with very dark brown organic matter. These aggregated coatings are noticeable thinner or absent at grain edges and corners.

Crudely laminated, very thin clay skins coat most grains in a narrow irregular horizontal zone approximately 2 mm. thick. Along the upper edge of this zone, the clay coatings are thicker than average (20 to 50μ), commonly forming bridges between grains and clogging interstitial pores. Composition of this clay apparently varies through a narrow range; colors have different values of strong brown and relief varies from low positive to low negative.

High power. Occasional partially decomposed plant parts occur, but most organic matter is in the form of minute ($\sim$10μ) irregular equidimentional specks. Fresh grass opal is ubiquitous, accounting for approximately 2% of the mineral grains.

Walla Walla silt loam A_{12} 10-11"

Low power. Interiors of prisms are composed of moderately compact, angular to subangular silt, very fine sand and fine sand. Most grains are coated with aggregated organic matter and clay. Packing of grains is more dense at ped faces and around tubular pores. The largest common grains are sand-size volcanic rock fragments, many of which contain plagioclase phenocrysts. Approximately 75% of the pore space is interstitial between grains, the remainder occurs as tubular pores (1 to 2 mm in diameter).

Medium power. Arrangement of skeletal grains is massive, except for a few, dense, well rounded, darker bodies, resembling iron oxide concentrations seen in soils of western Oregon. Grains lining pores are cleaner than the majority. Grass opal makes up at least 2% of the solid material in the section.

High power. A few silt grains in more porous sections have very thin (5 to 10μ) coatings of pale purple, isotropic material of low negative relief.

Walla Walla silt loam AC_2 30-31"

Low power. Angular silt and very fine sand grains are randomly and somewhat loosely packed. Very fine tubular pores with walls darker and denser than average for the horizon are common. Many coarser pores are partially filled with loosely packed silt grains. Sand and coarse sand-size fragments of zoned plagioclase, hypersthene, rock fragments and hornblende constitute 5 to 10% of the skeletal fraction.

Medium power. Material coating skeletal grains is darker in color and less well oriented than that in lower horizons. Very thin ($<10\mu$), discontinuous coatings of isotropic, transparent, very pale green material occurs in some pores. What appear to be fragments of these coatings are often more noticeable on pore walls than the coatings as such. Some plagioclase phenocrysts have visible remnants of pumiceous glass adhering to them. All such phenocrysts are discontinuously coated with a dark brown, semi-opaque, clayey substance of low birefringence, showing slight optical orientation parallel to surfaces coated.

High power. Some pores have thin (5 to 20μ), discontinuous colloform coatings of clear, very pale green, isotropic material of low positive relief. Fine silt-size spheroidal blobs of similar material are associated with these coatings.

The 22 to 23 inch section differs from that at 30 to 31 inch in containing approximately twice as much pyroclastic plagioclase and associated pumice.

Walla Walla silt loam C_{12} 61-62"

Low power. Randomly oriented, moderately angular to subrounded silt and very fine sand grains of rock fragments, feldspar, quartz, muscovite, biotite, hornblende and magnetite are covered with thin, brown coatings. Fine tubular pores occupy 3 to 5% of the section. Immediately adjacent to pores the silt grains appear to be packed more closely.

Medium power. Aggregated grain coatings vary from 0 to 20μ in thickness and are present on most grains. Surfaces forming walls of tubular pores are noticeable cleaner than the rest of the grain. The clean appearance of pore walls is heightened by a very thin, though widespread, coating of isotropic, transparent, very pale green substance.

Somewhat opaque grass opal is widely distributed although it constitutes less than 1% of the mineral matter.

High power. Thinner coatings ($<5\mu$) are composed mostly of yellowish brown, moderately to strongly oriented, moderately birefringent clay. Thicker coatings (5 to 20μ) contain fine silt grains and organic matter as well as slightly oriented clay displaying first order interference colors.

Coatings are generally thicker on flatter or concave grain surfaces and thin or absent at protuberances. Relative to grain size, the thickest coatings occur on flakes of mica.

Walla Walla silt loam C_{ca} 94-95"

Low power. Randomly oriented, somewhat loosely packed, angular to sub-rounded, coarse silt and very fine sand grains of rock fragments, feldspar, quartz, muscovite, magnetite and hornblende are discontinuously coated with dark brown organic matter. Tubular pores (.2 to 1. mm) are nearly devoid of aggregated coatings and silt grains immediately surrounding them appear to be more closely packed than in the horizon in general.

Medium power. Most grains are coated, particularly on smoother surfaces, by moderately birefringent clays displaying moderate to strong optical orientation parallel to the grain surface. Thicker coatings (10 to 20μ) show much weaker orientation of clay particles, probably due to numerous included fine silt particles. Where coatings are thickest, they form bridges between grains and fill some interstitial pores. Where coatings are thinnest (<5) they are much lighter in color and discontinuous. Some of the more thickly coated areas are in the form of irregular, roughly horizontal streaks, while some of the more thinly coated areas appear to be pore fillings.

High power. Except for jagged terminations on occassional hornblende and olivine grains even faint traces of weathering are lacking. Thicker, less transparent coatings could conceivably obscure a slight degree of weathering.

A pale green, clear substance with moderate positive relief

Fig. 25
Walla Walla silt loam A_{12} 10-11"
70μ

1. Sand size volcanic rock fragment with very dark brown organic coating (2). 3 and 4. Lighter and darker, isotropic coatings of aggregated organic matter, clay and fine silt.
5. Tubular pore 6. Ground mass of angular, coated silt grains.
Rod shaped particles are grass opal.

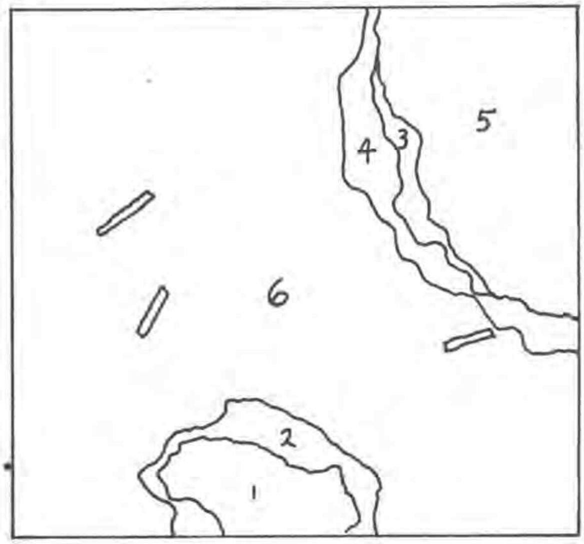


Fig. 26
Walla Walla silt loam AC_1 30-31"
70μ

1. Sand size plagioclase with very dark brown organic coating (2).
3. Zone of clean grain surfaces.
4. Tubular pore 5. Ground mass of angular, coated silt grains.
Coatings are thicker where the picture is darker. Rod shaped particles are gráss opal.

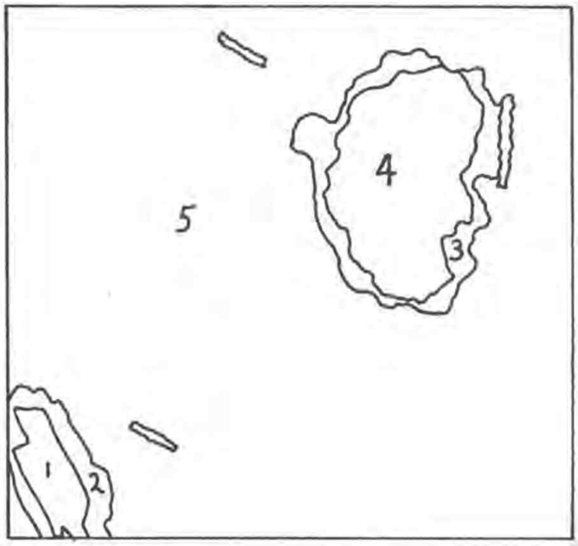
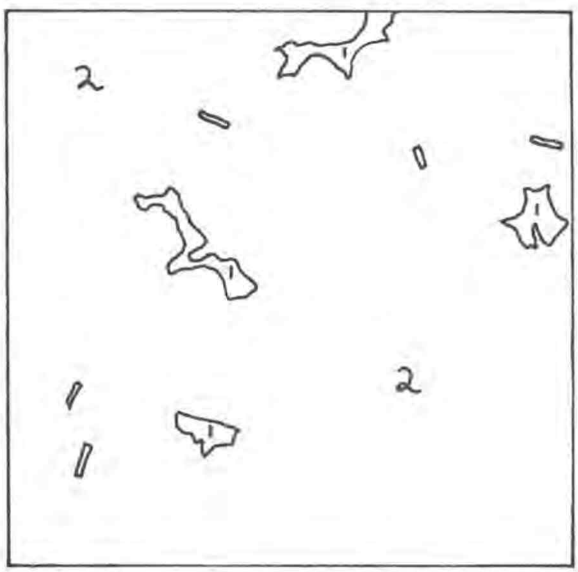
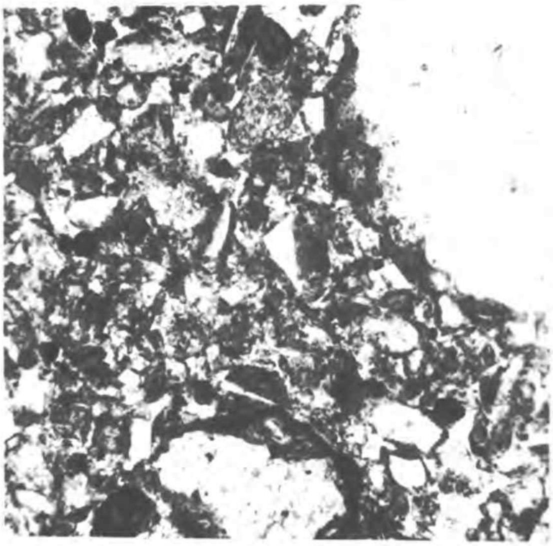
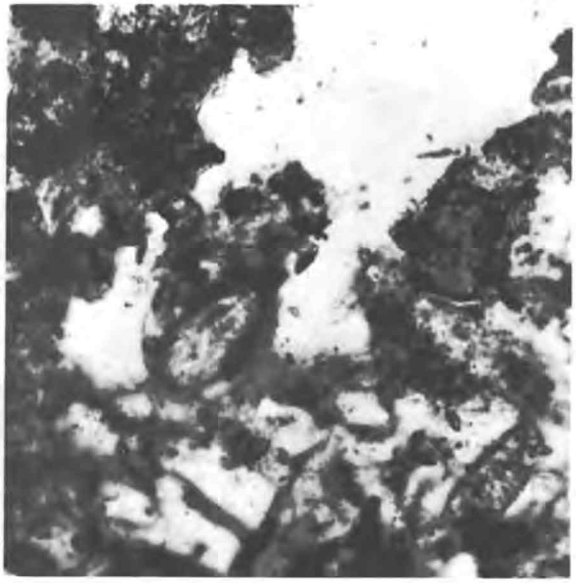


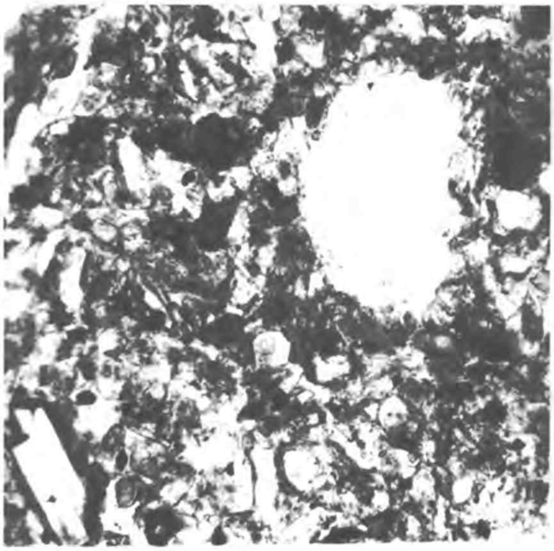
Fig. 27
Walla Walla silt loam C_{ca} 94-95"
100μ

1. Interstitial pores 2. Angular, coated, coarse silt and very fine sand grains.
Rod shaped particles are grass opal.









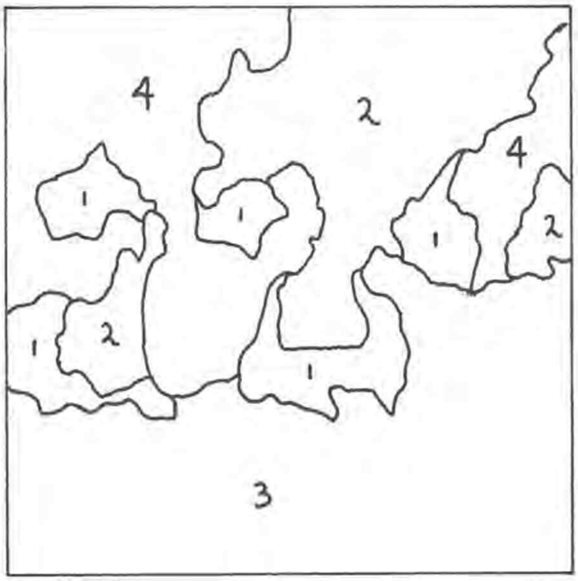


Fig. 28
Walla Walla silt loam A_{1pm} $7\frac{1}{2}$-8"
50μ
1. Concentrations of oriented clay. 2. Pores 3. Compact silt, clay and organic matter. 4. Organic rich, aggregated silt, organic matter and clay.

Fig. 29
Walla Walla silt loam AC_1 15-16"
25μ
1. Interstitial pores 2. Coated mica flakes 3. Coated plagioclase grain 4. Aggregated silt grains

coats some pores (5 to 20μ thick) and forms bridges between grains.

Many sand-size plagioclase phenocrysts retain traces of peripheral glass. Grass opal is a wide-spread, minor constituent. A few tubular pores were observed to be thinly coated with microcrystalline carbonate aggregates.

Interpretation

The entire profile gives the impression of youthfulness. Mineral grains appear to be unweathered except for a very few which could easily have been weathered prior to deposition. Clay-organic coatings on sand and silt grains appear to predate the present situation since they are thickest at the center of grain faces instead of at grain contacts. Several factors point to gradual, though intermittant, accretion of silt. Similarity of the nature, if not frequency, of pores; ubiquitous grass opal; absence of obvious buried horizons; and weak structural development could all be interpreted as indicating a gradual rather than catastrophic accretion of loess.

This hypothesis is consistant with at least one postulated explanation for the present loess distribution pattern in central Oregon (5, p. 95), which, if briefly put, states that the initial deposit thinned with increasing distance from the Columbia River and has been reworked by prevailing westerly winds. Loess is thickest at present on northerly and easterly slopes and thinnest on southerly and westerly slopes. There is no evidence in the thin sections that this resorting process is not still in effect.

The only feature even approaching illuvial clay skins in this profile are those occurring in a narrow zone just above the plow pan. These moderately oriented and crudely laminated coatings of clay occur in a region approximately 1 to 2 mm thick and appear to have been deposited by water moving laterally over the plow pan. It is difficult to say whether such clay films reflect time elapsed since beginning of cultivation or merely since the most recent plowing.

Ped faces and pore walls appear more densely packed and higher in organic matter than ped interiors. Compaction on prism faces could be explained by shrinking and swelling, that around pores is apparently due to growth of the roots, which are presumed to have created the pores. Apparent higher content of organic matter of peds and pore faces could be due to increased biological activity in these zones or to downward movement of material from the A horizons, or both.

Thin, clear, isotropic coatings of both pale green and pale purple material suggests similarities with some of the weathering processes dominant in the Lookout profile. These colloidal fractions are not concentrated in the Walla Walla due to its high porosity, hence it is difficult to judge whether they are more or less important. Because thin, isotropic coatings are discernible only on cleaner grains and around some pores, one is apt to conclude that such colloidal films are of only minor importance. There is doubtless a great deal more of this material than is readily visible in thin sections. The cemented nodules mentioned in the profile description are most likely cemented with one or the other of these colloidal substances.

Calcium carbonate was observed to occur only as discontinuous, drusy accumulations of minute crystals lining some of the pores in the lowest horizons examined. These accumulations might well be the result of one season's accumulation.

Although sand-size, pyroclastic plagioclase and pumice are distributed throughout the upper six feet of the profile, there is a distinct concentration of this fraction between 20 and 30 inches deep. While such evidence is hardly definitive, a concentration of this sort strongly suggests that the initial volcanic deposit occurred at this level in the profile.

Description of Thin Sections

Tolo silt loam A_1 $0-\frac{1}{2}$"

Low power. Sand-size granular aggregates of silt and organic matter are very loosely mixed with subrounded, coarse and very coarse sand-size pumice and angular plagioclase. Interstitial pore space accounts for 20% of the section. Pumice grains are coated with strong brown aggregated material. Glass which is surrounded by aggregated material is more highly devitrified than that within the grains.

Medium power. Plant opal is a conspicuous element of the silt fraction where not obscured by excessive organic matter.

Tolo silt loam A_3 2-3"

Low power. Very fine to fine (.25 to 2. mm) plates are composed of very fine granular aggregates of organic matter, silt and a small amount of clay. Grains of coarse sand-size pumice and plagioclase, usually coated with the aggregated material, are conspicuous in the plates. Most of the pumice is devitrified at grain margins and around larger internal pores. Dark brown coatings, up to 200μ thick, of aggregated organic matter, clay and silt are present on most mineral grains, especially pumice.

Medium power. Plates are porous (40 to 50% pore space) with common sand-size interstitial pores. Sand grains occasionally show thin coatings of opaline material, especially on plate perimeters.

Pumice grains are subrounded and show signs of weathering but crystalline mineral grains are angular and fresh. Next to pumice in decreasing order of importance are euhedral plagioclase crystals, usually ranging between sodic andesine and sodic labradorite in composition. These crystals are normally surrounded by vestiges of the pumice in which they were originally enveloped. They are characterized by Carlsbad twinning, zoning, solution embayment, and inclusions of subhedral magnetite. Enstatite, augite and magnetite are present in lesser amounts. A few sand-size fragments of fresh basalt are present also. Fresh, unbroken grass and pine opal is conspicuous, especially between plates, although it constitutes less than 2% of this horizon.

High power. Red-brown clay in aggregated coatings has low birefringence and is oriented parallel to the surface of the coated grain. Pumice appears somewhat darker (cloudy gray) than that occurring in soils examined from west of the Cascades.

Tolo silt loam C_1 $7\frac{1}{2}$-$8\frac{1}{2}$"

Low power. Very loosely packed, fine sand and very fine sand-size, spheroidal, granular aggregates are composed of glass shards, fine silt grains, grass opal and clay. Aggregates appear dense in contrast to the coarse network of interstitial pores which constitutes most of the pore space.

Sand-size shot, showing a wide range of expression, are present but make up only 1 to 2% of the soil material. Charcoal fragments are also widely distributed but not important in volume. A few sand-size grains of plagioclase (mostly andesine) and pumice are readily noted due to relatively large size. All feldspars display persisting remnants of pumice which originally enveloped them.

Medium power. All degrees of aggregation are represented from mere agglomerations of glass shards, silt grains, clay and grass opal to dense, spherical, reddish brown concretions containing the same constituents plus a presumably ferric cementing agent. Most grass opals occur between rather than within aggregates and therefore appear more abundant than is actually the case.

Tubular pores are few and irregular in outline with walls slightly cleaner than the soil material as a whole. Approximately 30% of the section is occupied by solid matter. Vertical channels have very thin, discontinuous coatings of pale green isotropic material of moderate positive relief.

High power. Spherical pollen grains approximately 10 μ in diameter and spheroidal blobs of opal 20 to 30 μ, probably from pine needles (24, p. 27), are conspicuous interstitial constituents at this magnification. Only a few glass shards are even slightly devitrified. A very pale yellow substance of low relief and low birefringence seems to bind aggregates together. Plant opal appears to constitute 20% of the solid material in this horizon, but since many forms are imperfectly known, the true content is probably higher.

Tolo silt loam C_1 14-15"

Low power. A few, very coarse sand-size, dark reddish brown, spheroidal, iron concentrations are scattered among very loosely packed aggregates composed of glass shards, silt grains, clay, grass opal and charcoal fragments. Sand-size grains of pumice and plagioclase encased in pumice are also present in minor quantities. The total percent of solid material is estimated at 40% or less. Aggregates appear somewhat denser than in the horizon above. Iron oxide concentrations commonly have discontinuous rims which are of normal density but show no sign of being iron stained. Tubular pores are common, but many are so full of aggregates as to be nearly indistinguishable. Walls of pores are more densely packed than the horizon as a whole.

Medium power. Crystalline silt and sand grains are approximately equal in volume to the isotropic constituents. Plant opal accounts for approximately 20% of mineral matter in the section.

High power. Dark reddish brown mycelia (5μ in diameter) are ubiquitous. A few partially decomposed rootlets are coated with clear, pale purple, isotropic material.

Tolo silt loam C_3 28-29"

Low power. Spheroidal, fine sand-size aggregates of crystalline silt grains, glass shards and plant opal appear denser than in overlying horizons. Interstitial pore space is somewhat lower (40 to 50%), and tubular pores are less common.

Medium power. Crystalline grains are more prevalent than in high horizons. Some areas are packed tightly enough to obscure individual aggregates.

Tolo silt loam B_{21b} 37-38"

Low power. Very common, irregular, tubular pores riddle material massive in appearance, which is composed of moderately packed fine sand-size aggregates of crystalline silt, glass shards, and plant opal. Very angular crystalline silt predominates over isotropic constituents and most pore space occurs as tubular pores. Dark reddish brown, coarse sand-size, spheroidal iron oxide concentrations are common. Pore margins are darker than the horizon in general but fluidal coatings are absent.

Tolo silt loam B_{21b} 39-40"

Low power. Massive, somewhat densely packed, crystalline silt, glass shards and plant opal is riddled with irregular, tubular pores. Approximately half the pores contain moderately thick coatings of well oriented, laminated, brownish yellow clay, showing low second order interference colors.

Medium power. Laminations in clay skins are accentuated by lenticular accumulations of clay-size particles of dark reddish brown material at frequent intervals. Those portions of the section which lack clay skins differ little from the overlying horizon.

Fig. 30
Tolo silt loam A_1 $0-\frac{1}{2}"$
320 μ

1. Sand size pumice grains with very dark brown coatings (4) 2. Pore space 3. Very fine platy aggregates

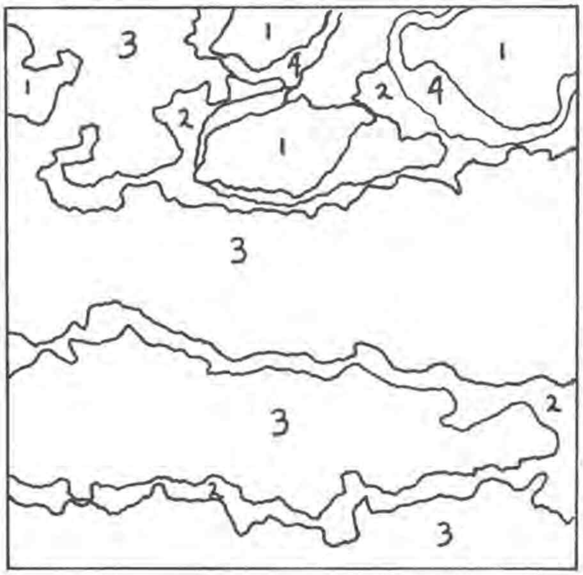


Fig. 31
Tolo silt loam C_1 13-14"
70 μ

1. Grass opal in decaying plant tissue 2. Irregular aggregations of plant opal, volcanic glass shards, and organic matter
Rod shaped particles are grass opal, irregular spheroidal phytoliths are probably from coniferous trees.

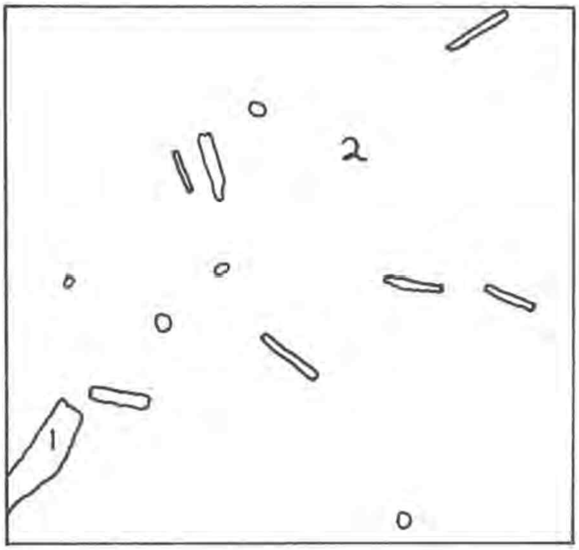
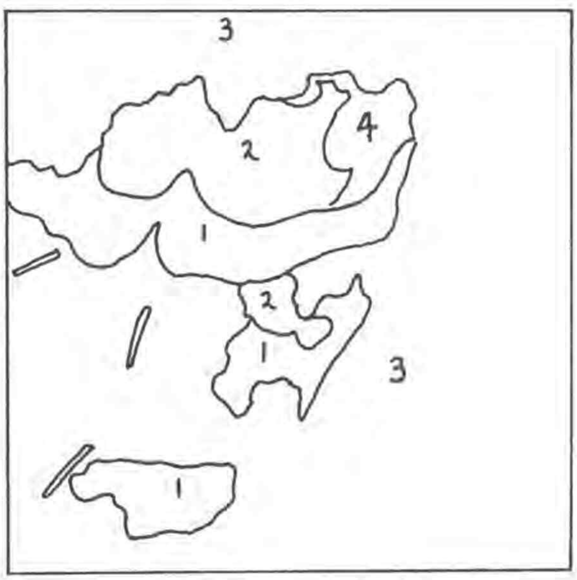
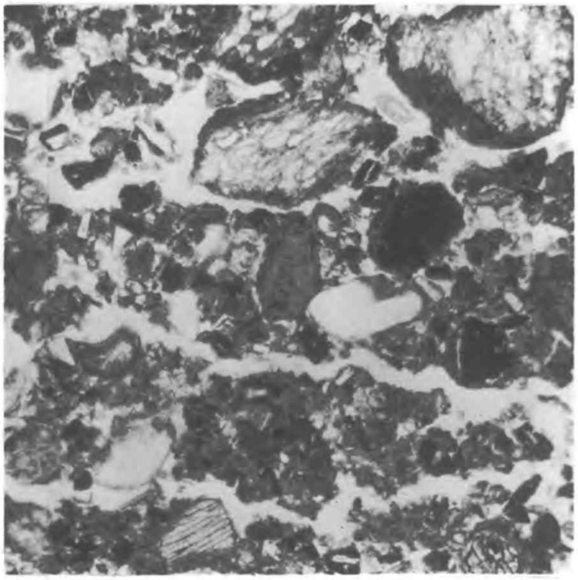
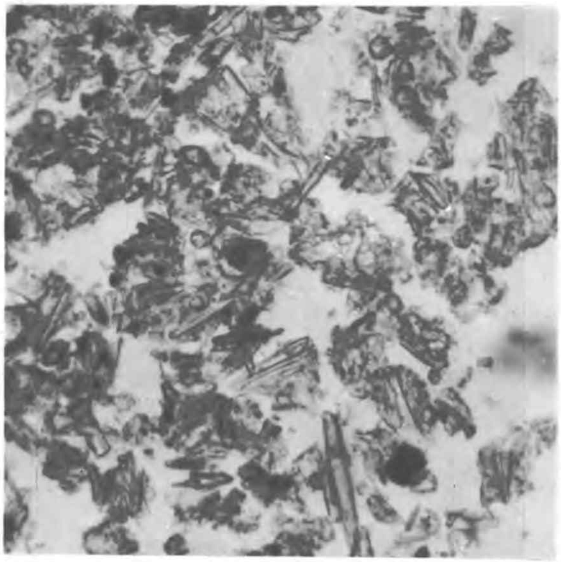


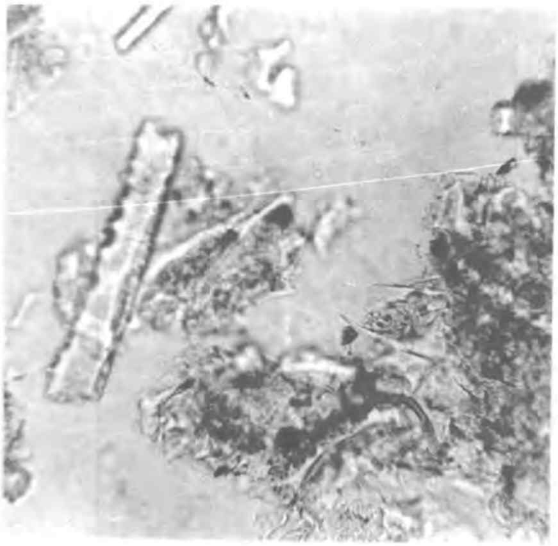
Fig. 32
Tolo silt loam B_{21b} 39-40"
70 μ

1. Laminated concentrations of oriented clay 2. Pores 3. Closely packed silt, clay and plant opal 4. Unlaminated, silty, clay concentration









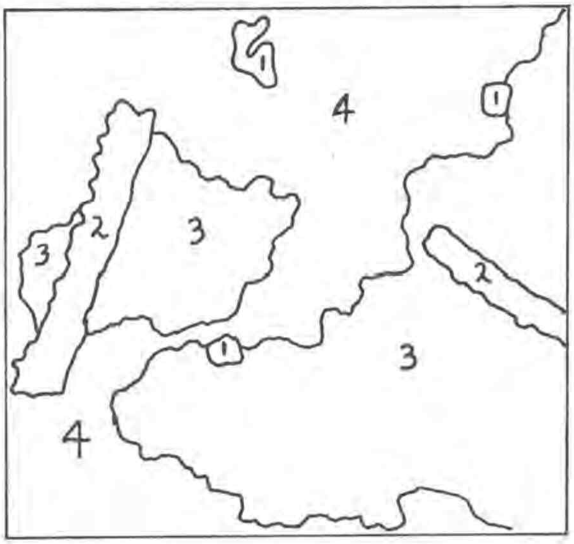


Fig. 33
Tolo silt loam C_1 14-15"
25μ
1. Conifer opal 2. Grass opal
3. Irregular aggregates of volcanic glass shards, plant opal and organic matter
4. Void

Tolo silt loam B_{22b} 42-43"

Low power. Densely packed, angular silt grains are traversed by numerous, irregular, tubular pores. Spheroidal to irregular, coarse sand-size, dark reddish brown iron oxide concentrations are common. Thin, reddish brown, poorly oriented coatings occur in some pores; they resemble the darker fraction of clay skins in the horizon above.

Tolo silt loam B_{32b} 74-76"

Similar to the horizon above, except that most pores contain moderately thick, brownish yellow, well oriented, laminated clay skins, displaying moderate to high second order interference colors. Discontinuous, moderately oriented, unlaminated, clay skins occur within the laminated ones. Pale purple, isotropic, coatings (commonly containing silt grains) constitute the innermost coating.

Interpretation

Except for sand-size pumice and pyroclastic plagioclase, which dominate the surficial horizons, the principal elements constituting the Tolo profile are silt-size volcanic ash, crystalline mineral fragments, and plant opal. Since both loess and volcanic ash are commonly recognized in eastern Oregon, the surprising quantity of plant opal present in this soil deserves attention. Soils have been described from Japan and islands in the Indian Ocean (18, p. 426; 12, p. 65) which contain higher percentages of plant opal. These soils are developed from volcanic ash or basalt, and the example from

Reunion (18, p. 426), at least, has a climate not markedly different from that prevailing at the Tolo site from which these samples were obtained.

It seems quite plausible -- given vegetation which contains phytoliths, a climate not conducive to leaching, and a parent material which is more soluble than plant opal -- that the opal phytoliths could accumulate until they formed the major skeletal portion of the soil. Most of the trees now occupying this particular site are known to produce opal in varying degrees (18, p. 427; 24, p. 27). Grassland is widespread in the area, especially on southerly exposures. Both silt grains and grass opal could easily be wind transported to, and deposited in, the nearest grove of trees.

The increasing percent of crystalline silt, relative to glass shards and plant opal, with increase in depth could reflect the character of the original deposit or the fact that grass opal and volcanic ash are added only at the top.

Laminated clay skins which occur irregularly in the very common pores of the highly vesicular buried profile would most logically derive from weathering products of the Tolo profile. In spite of the highly developed nature of these clay skins, pores in a large fraction of the section are devoid of fluidal clay of any kind. Such a lack of clay skins may indicate that many of these pores are not continuous channels, but merely occluded voids of some kind. Although these well developed clay skins appear to have formed in the porous A horizons of the buried soil, enough ashy material has moved down from the upper sequence of horizons to render the contact somewhat obscure.

Whether these laminated clay skins occur at the base of the upper sequence of horizons or in the upper most part of the lower sequence, they appear to be derived from the ashy upper material, either by eluviation or crystallization. Since crystalline clay is not apparent in the upper sequence, it seems logical to conclude that clay derived therefrom must be entirely secondary. There is, however, always the possibility that the parent material for the upper sequence contained crystalline clay originally.

Common, highly concentrated iron oxide concentrations and polygenetic clay accumulations in pores suggest more than a passing similarity with the Woodburn profile already discussed. If this postulated resemblance is a real one, such a profile would most likely have developed under more moist conditions that prevail at present. The interval between 8000 years B.P. and termination of Wisconsin glaciation (10, p. 119) seems most apt to meet the required environmental conditions.

The coarse sand-size pumice, plagioclase and hypersthene which distinguish the A_1 horizon must be a very recent deposit. This youthfulness is attested to not only by superior stratigraphic position but by lack of mixing with underlying finer textured material.

Description of Thin Sections

Lookout silt loam A_{11} 2-3"

Low power. Very fine, subrounded, granular aggregates of silt, sand, clay and organic matter form fine to medium subangular blocky peds. Approximately half of the section consists of granular aggregates, some of which are distinguishable by denser, darker margins and bounded by interstitial pores, where not in contact with another ped. Sand grains, especially those of pumice, are coated with aggregated silt, organic matter and clay. Moderately weathered fragments of the trachytic basalt which underlies the profile are the coarsest skeletal constituents. A few (approximately 5% of profile) coarse sand-size lumps of material from the B horizon are present, usually with coatings of A horizon material sufficiently thick to render them inconspicuous to the naked eye. A majority of visible pore space is interstitial between granular aggregates.

Medium power. Very thin films ($<10\mu$) of opaline material can be observed coating some peds and at contacts between grains, but are not nearly so thick or numerous as in lower horizons. Comparatively clean silt and very fine sand grains occur in spaces between aggregates.

High power. Grass opal and glass shards, the latter usually coated with aggregated silt and organic matter are a conspicuous, though minor constituent of the silt fraction. Many glass shards have very thin (1 to 2μ) coatings of highly oriented, moderately birefringent clay and organic matter. Of those sand grains (plagioclase and hypersthene) which are visibly coated, the majority still retain an envelope of the pumice in which they originally occurred. Monomineralic grains appear quite fresh, but in sand and silt-size fragments of basalt, and pumice to a lesser degree, the glassy matrix has frequently undergone complete devitrification. Grains so altered have a thick covering of aggregated organic material.

Lookout silt loam A_{12} 7-8"

Low power. Moderately dense, dark brown, fine, subangular blocky peds of fresh, clean angular to subangular silt and sand grains, clay, volcanic glass shards, and organic matter are separated by roughly parallel cracks. Margins (.5 to 1.0 mm thick) of some peds are darker and denser than interiors, with less sand and clay. Cracks between blocky peds account for most of the pore space within the horizon when the soil is dry. A considerable proportion of pore space within peds is in the form of tubular (.1 mm to .25 mm in diameter) pores, some of which have opaline coatings 2 to 10μ thick. Three quarters of the pore space within peds is interstitial between silt grains, with average pore diameters on the order of 5μ and less.

Medium power. A few tubular pores, especially those with darkened peripheries, have films of weakly oriented clay immediately outside the dark layer. Units of aggregation smaller than the above mentioned subangular blocky peds are not evident. Clean, angular, coarse silt and sand grains stud a matrix of fine silt, clay and organic matter which is aggregated on a scale too small to be discerible. Pumice trains are the only skeletal constituents displaying visible coatings of aggregated material. Clean silt grains and grass opal project from or cling tenuously to the surface of peds.

High power. Increased magnification fails to resolve any pattern of organization in the aggregated matrix of fine silt, clay and organic matter. Some sand and coarse silt grains have very thin coatings of oriented clay on larger faces.

Lookout silt loam B_1 $8\frac{1}{2}$-$9\frac{1}{2}$" (top of prism)

Low power. Yellowish brown, dense, fine to very fine, angular to subangular blocks of clay and angular silt and sand form medium size prisms and display a tendency to exfoliate on drying, especially at the top and sides of prisms. Angular to sub-rounded unweathered sand and silt grains are firmly embedded in the clayey matrix of the peds. Most clay occurs as random flakes, but preferred orientation is evident on exterior surfaces of some peds, adjacent to mineral grains and rock fragments, and in pores within peds. Streaks of oriented clay cut across peds without apparent reference to ped structure.

Medium power. Pore space within peds is low, averaging less than 10%, and consists mostly of fine tubular pores and very fine cracks. Characteristic units of aggregation smaller than those observed under lower magnification do not appear to exist. Lenticular fragments of darker, clay-rich material occur between, or adjacent to, peds and are commonly coated with moderately oriented clay. Cracks associated with streaks of oriented clay are both curved and straight. Oriented clay on ped surfaces is similar to that within peds except that the former often contains a lower percentage of silt grains. The only visible evidence that crystalline minerals have undergone chemical disintegration in their present situation consists of iron-oxide-stained, oriented clay adjacent to some fragments of weathered basalt. Monomineralic grains appear quite fresh.

High power. Oriented clay surrounding sand and silt grains appears similar in arrangement and composition to clay skins coating peds and the streaks of oriented clay within them. Clay in all three types of occurrence is brownish yellow, displays weak pleochroizm, low positive relief, moderate optical orientation, and moderate birefringence. Regular lamination is lacking, and boundaries with matrix material are gradual to diffuse. These coatings can properly be considered "stress cutans" as defined by Brewer (2, p. 286). Optical properties indicate an iron-bearing montmorillinoid as the dominant clay mineral.

A clear, pale green substance, of low to moderate positive relief covers the topmost surface of prisms with a thin (5 to 50μ), irregular, colloform coating. Fine silt-size spheroidal blobs of this substance adhere to and are imbedded in the coating. One to two centimeters down the sides of prisms these coatings thin rapidly, becoming discontinuous or absent. Where these coatings and agglomerated blobs are thickest (50 to 100μ) their inner portions are distinctly crystalline, exhibiting first order yellow interference colors.

Lookout silt loam B_2 16-17"

Low power. Dense, fine, blocky peds, which make up fine prisms, are composed of densely packed clay, silt and sand. Ped surfaces are bounded by slightly oriented silty clay which merges gradually into the ground mass. Similar, though thinner, streaks criss-cross many peds. Angular to rounded coarse sand-size grains of quartz, feldspar and oxidized trachytic basalt are the dominant coarse, skeletal constituents.

Medium power. Major, vertical ped faces are darker than interiors due to increased silt and organic matter. Clay in smoother ped faces is moderately oriented. Degree of orientation is greatest at the face and decreases rapidly inward. Around most larger sand grains, clay is more highly oriented than that at ped faces. Oxidized basalt grains resemble underlying rock, while most feldspars are of either acid igneous or pyroclastic origin. Sand-size quartz is derived from coarse grained, acidic intrusive rocks. Mafic minerals (very fine sand to silt-size) are predominantly augite, hornblende and pyroxene, and show signs of weathering in place, other monomineralic constituents do not.

High power. Silt-size fragments of mineral grains, rock, organic matter, plant opal and oriented clay are firmly embedded in moderately birefringent, brownish yellow clay.

Lookout silt loam B_{3Ca} 23-24"

Low power. Brown, dense, fine subangular blocky peds are composed of densely packed, coarse sand-size, spheroidal aggregates of clay and silt. Angular to rounded sand grains of quartz, feldspar and basalt make up 5 to 10% of the peds.

Medium power. Ped surfaces and pores are discontinuously covered with coatings of fine sand-size, spheroidal aggregates of highly birefringent clay and carbonate. Some pores appear to be completely filled with such aggregates. Moderately oriented clay occurs at some curved fracture surfaces but most oriented clay occurs within peds as random flakes. Basalt fragments without exception are highly oxidized.

High power. Aggregated coatings are highly charged with silt, and those on major ped faces (those continuous with upper B) are rendered dark brown by their high content of organic matter. Fragments of grass opal are not uncommon constituents of these darker coatings.

Lookout silt loam C_{ca} 26-27"

<u>Low power</u>. Moderately birefringent, silt and sand-size, spheroidal aggregates of clay and carbonate fill spaces between slightly weathered fragments of the underlying trachytic basalt. Packing of the aggregates ranges from very loose (~75% pores) to dense (~25%). Fragments of thick (~250) moderately birefringent, slightly pleochroic, strongly oriented, laminated clay skins are common. Many of these fragments have thin coatings of yellowish brown, pleochroic clay showing weak orientation parallel to the surface of deposition. Sand and silt-size grains of quartz and feldspar are widely scattered but make up less than 5% of the horizon. Fragments of basalt have moderately thin coatings of dark yellowish brown, isotropic to very weakly birefringent material which grades abruptly to fresh basalt.

<u>Medium power</u>. Clear isotropic, pale purple, colloform coatings of moderately negative relief occur widely but account for only 1 percent of the solids within the profile. They can be observed on surfaces of thick clay skin fragments as well as on the surface of the thinner yellowish brown clay skins which envelope the thicker ones, and around fragments of basalt. Granular aggregates appear to consist mostly of moderately birefringent, very fine silt and coarse clay-size particles, flocculated into rather dense blobs. Not infrequently these blobs possess thin coatings of moderately oriented, moderately birefringent, yellowish brown clay. A few subangular, sand-size peds from the B horizon, some completely

bounded by thin clay skins, are firmly embedded in the matrix of flocculated aggregates.

High power. Very fine, silt and clay-size, moderately birefringent particles of undetermined shape, and with indexes of refraction ranging from less than that to more than that of the resin, are agglomerated into very light brown aggregates of varying densities. Carbonate and clay, in varying proportions, are the most likely components.

Lookout silt loam C_m 29-30"

Low power. Angular, gravel-size fragments of trachytic basalt are embedded in dense, very pale brown, aggregated material, displaying moderate to high aggregate birefringence. Crude, colloform, laminae occur parallel to surfaces of the rock fragments. Spaces between the dense laminated material are filled to varying degrees with spheroidal aggregates similar to those in the horizon above.

Approximately 10% of the section consists of highly colloform, finely laminated, isotropic material, of moderate, negative relief, varying from clear and colorless to a turbid, pale brown.

Medium power. Many spheroidal aggregates have thin colloform coatings of moderately oriented (10 to 50μ thick), clear, very pale green to pale brownish yellow, moderately birefringent material of low negative relief. These layers are in turn discontinuously coated with a thinner layer of similar color, but which varies between

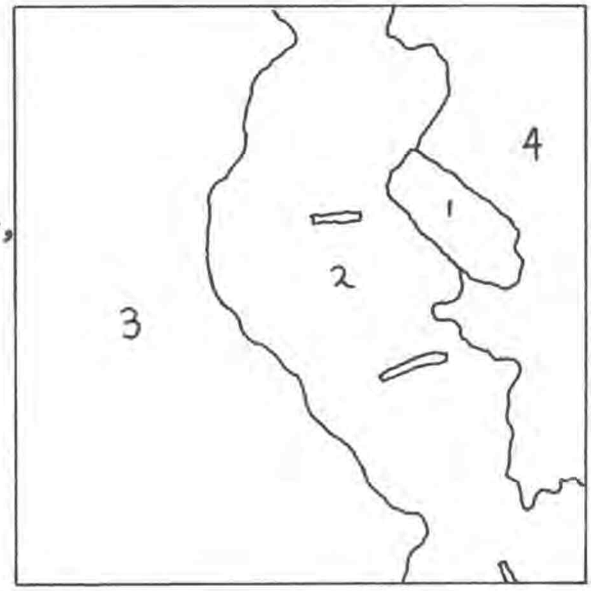


Fig. 34
Lookout silt loam B_1 8-9"
100µ
1. Very fine sand grain
2. Aggregated organic matter, silt, and grass opal coating a prismatic ped.
3. Clay rich portion of a prismatic ped 4. Void

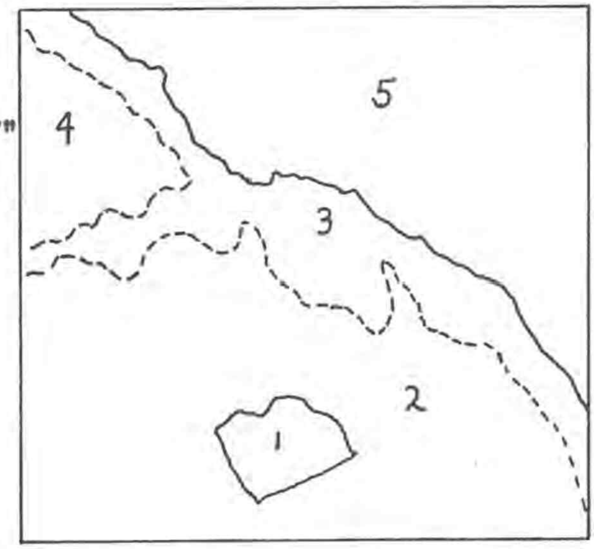


Fig. 35 polarizers crossed
Lookout silt loam B_2 16-17"
25µ
1. Sand grain 2. Matrix of clay, silt and sand
3. Oriented, unlaminated clay on ped surface
4. Matrix material high in organic matter 5. Void

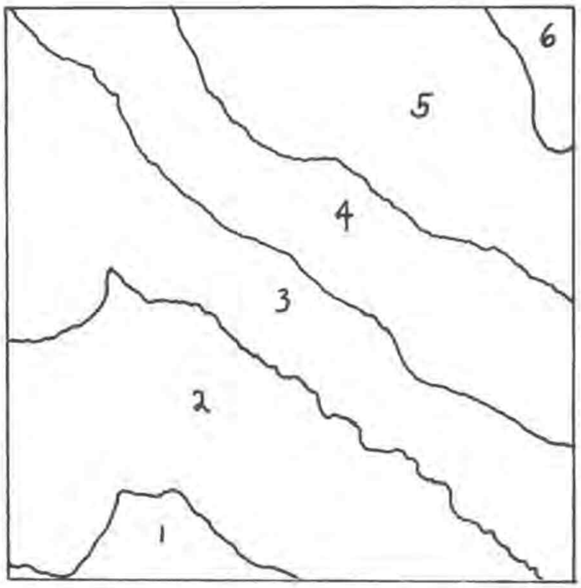
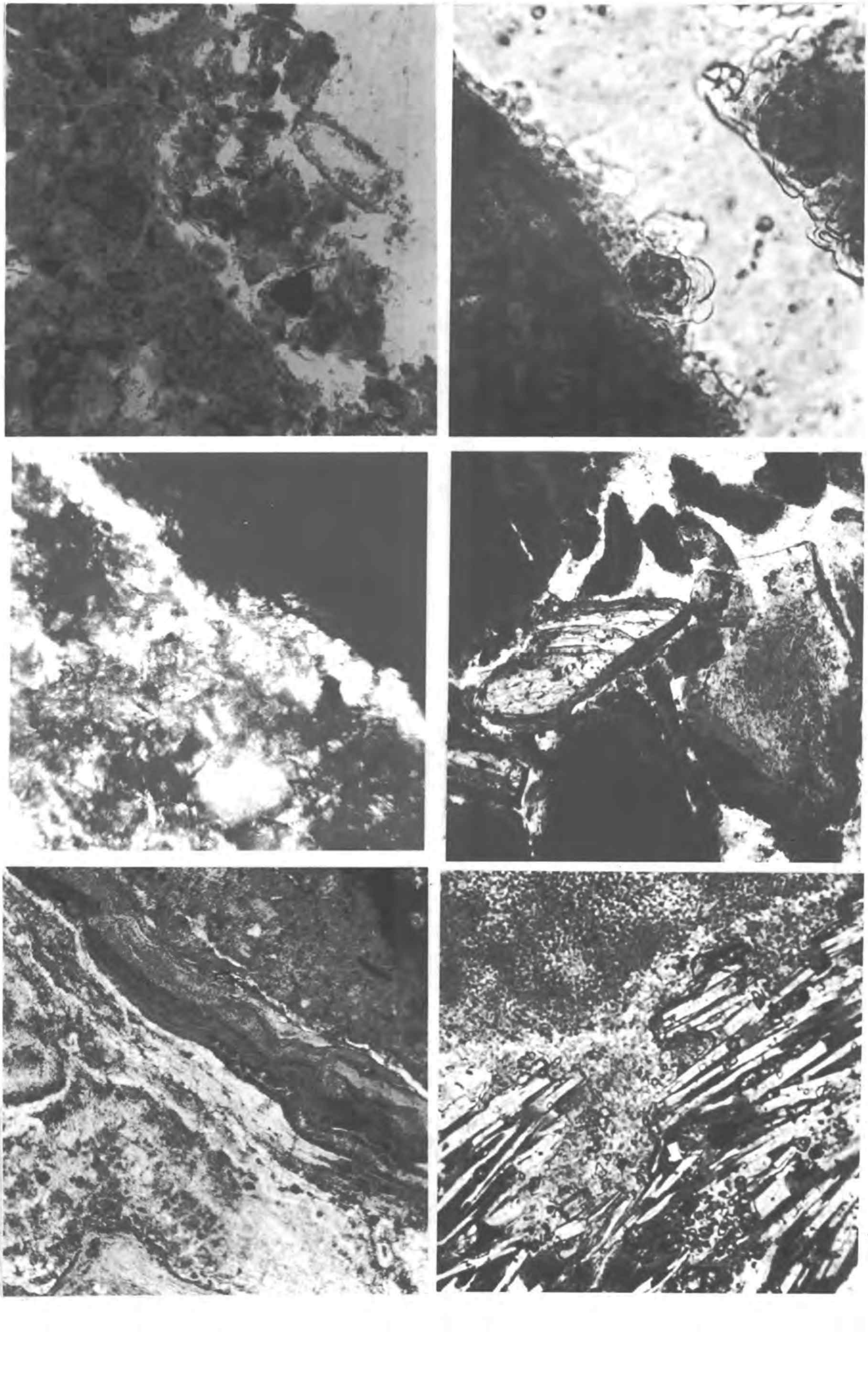


Fig. 36
Lookout silt loam Cm 29-30"
320µ
1. Thick, highly oriented clay 2. Aggregated, light brown, opaline material
3. Clear, banded, colloform opal 4. Milky, banded opal
5. Dense, microgranular, clay and carbonate
6. Aggregated carbonate



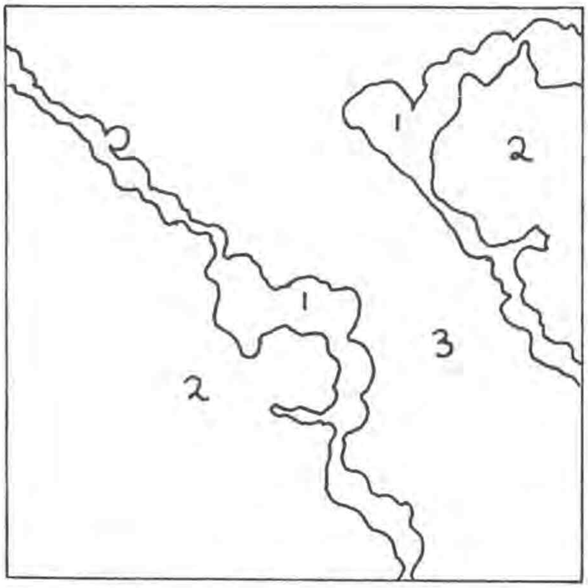


Fig. 37
Lookout silt loam B_1 $8\frac{1}{2}$-$9\frac{1}{2}$"
50μ
Top of prism
1. Clear, pale green, isotropic material, coating colloform, yellowish brown clay, organic matter and silt (2) 3. Void

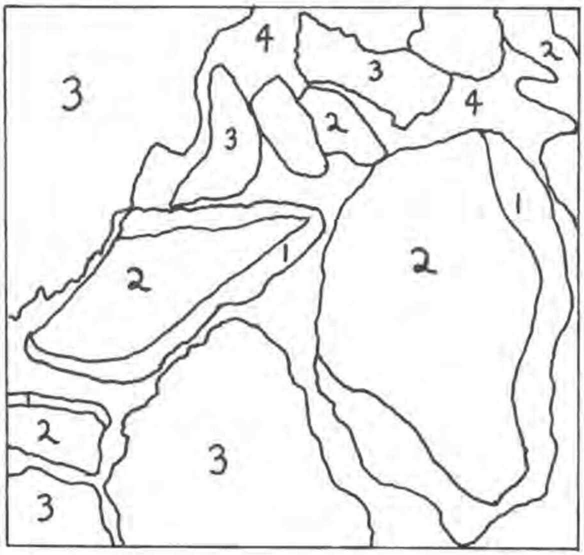


Fig. 38
Lookout silt loam Cca 26-27"
100μ
1. Yellowish brown coatings of oriented clay 2. Fragments of thick, highly oriented clay skins 3. Aggregates of micro-granular carbonate and clay 4. Interstitial pores

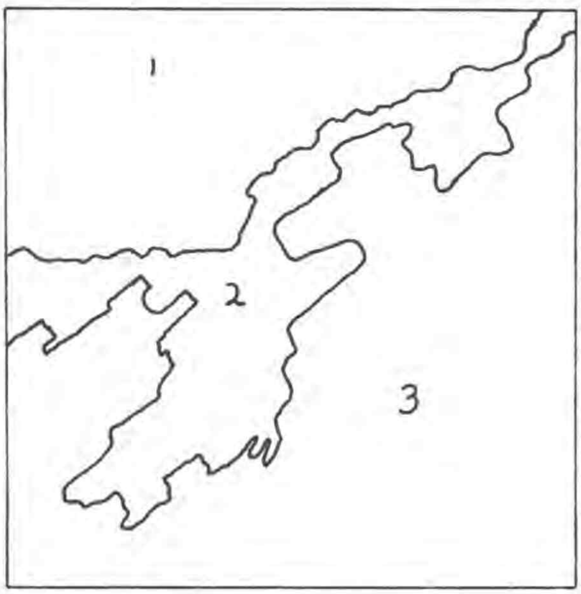


Fig. 39
Lookout silt loam Cm 29-30"
50μ
1. Massive, microgranular carbonate and clay 2. Similar material replacing bedrock. Feldspar laths appear more resistant than interstitial glass. 3. Trachytic basalt, with fresh feldspar crystals projecting into the carbonate.

isotropy and irregular low birefringence. Where aggregates are small, the volume of material in coatings exceeds that of aggregates proper. Contact between aggregated carbonate and basalt fragments is sharp. Rock fragments have anextremely fresh appearance. In many places carbonate has etched tortuous cavities, which extend up to .5 mm into the rock. Relatively pure carbonate adjacent to fresh rock is often separated from less pure interstitial aggregates by a zone of clay accumulation.

High power. Plagioclase laths project into the carbonate from the rock fragments. Glass matrix of the rock appears to etch more rapidly than crystalline components. Sand-size chips of basalt adjacent to larger fragments appear to have been isolated by the action of the carbonate on the rock.

Thin, isotropic coatings on some spheroidal blobs show moderate negative relief. Silt-size, spheroidal blobs of similar material also occur in association with the coatings.

Interpretation

Since the possibility that loess or volcanic ash may have strongly influenced the A horizon is mentioned in the profile description, it is not surprising to find the upper part of the soil dominated by sand and silt-size constituents foreign to the local bedrock. Acid igneous constituents have their most likely source in the granitic highland, which is 10 to 20 miles southwest up the Powder River from the site under consideration. The present flood plain is scarcely a mile distant, and finer particles could easily have been transported to their present place by wind. The presence of larger sand grains might not be so easily explained.

Concentration of grass opal on top of prisms indicates downward movement of silt-size particles at least within the A horizon. Such a conclusion is warranted whether one considers the opal phytoliths to be present as part of a loess mantle or as originating from grass growing on the surface.

Dark margins on prismatic peds of the B horizon appear to consist of included material from former silt coats. As cracks between prisms in the B horizon widen due to drying, loose particles of silt, very fine sand and organic matter are washed, or fall, down vertical cracks. Subsequent expansion of prisms on being wetted smears this organic rich material against ped exteriors with sufficient force to incorporate it.

In places, fresh silt coats are present on ped surfaces, separated from older, incorporated silt coat material by a thin layer of oriented clay. The dark margins are commonly composed of dark brown, silty lenses separated by curvilinear streaks of oriented clay.

Simultaneous occurrence of aggregated carbonate and opaline material as discrete concentrations suggests possible alternating conditions. The frequency of such changes is open to question. It seems reasonable to suppose that volcanic glass plays a role analagous to that attributed to carbonates in humid, temperate environment (4, p. 279; 8, p. 343). Being more easily weathered than most crystalline minerals present, volcanic glass might become completely altered and perhaps even removed from the profile, before weathering of crystalline minerals commences. Successive accretions of volcanic ash could explain alternating layers of calcareous and silicious precipitations, without resorting to postulated changes in climate, if the ash were assumed to have weathered more rapidly than the crystalline minerals. Since old soils are more apt to have experienced changes in climate, it is safe to assume that effects due to surficial accumulations are apt to be blended with those resulting from alteration of climate.

Since a large majority of the silt and sand fraction is mineralogically foreign to the bedrock, origin of clay is also cast into doubt. Under reflected light, many of the weathered fragments of bedrock have a color identical with that of the clay. No resistant minerals are apparent in this rock. Once a fragment has been thoroughly altered to secondary minerals there would be no evidence of its passing. Although larger quartz and feldspar grains appear fresh, silt-size pyroxenes and amphiboles show physical disintegration if not alteration to secondary minerals. Vigorous shrinking and swelling so dominates the B horizons that alteration products are probably incorporated shortly after their formation. It is safest to assume that clay in the B horizons derives both from under lying basalt and surficial silt. The relative importance of contributions from these two sources probably varies considerable from place to place.

The pale green, isotropic material which coats prism caps, approaches the optical properties of hydrous alumina gel or a mixture of alumina and silica gels. Mode of occurrence suggests that this material derives from weathering of constituents in the A horizons. There is a possibility, however, that this amorphous material could be extruded from peds of the B horizon as they contract on drying. In either case, at least part of this amorphous material appears to form clay, eventually, which is very similar to that which dominates the B horizons.

Organic matter and grass opal increase markedly toward the tops of prismatic peds. The fact that streaks of oriented clay surround much of this darker, aggregated material suggests that the B horizon is encroaching on the lower A horizon.

Replacement of fresh underlying rock by carbonate, or a mixture of carbonate and clay, suggests the possibility that such a mechanism might be of considerable significance in developing clay-rich soils wherever carbonates are concentrated immediately below the clay. Concentrations of clay between carbonate adjacent to rock fragments and interstitial aggregates may indicate the original outline of the fragment being replaced. A mixture of carbonate and clay would tend to replace rock during dryer periods. Under more humid conditions the carbonate would be displaced down the profile, leaving the clay residually concentrated in the B horizons.

General Discussion

Astoria, Quillayute and Jory

The Quillayute and Astoria profiles and the A horizon of Jory have much in common morphologically. Organic matter content apparently decreases and iron oxide content increases in the order listed. All three are composed of granular aggregations of agglomerated organic matter, amorphous colloids, and crystalline silt grains. Due to this high degree of granulation, interstitial pores are extremely abundant. Silt-size, spheroidal agglomerations appear to be moving down tubular pores in all three profiles.

Since the B horizons appear to be influenced considerably by parent material, study of similar soils, displaying a minimum of parent material influence should aid in understanding the dominant processes contributing to profile development.

It might be highly instructive to treat the range of properties spanned by these three soils as a continuous series, rather than trying to make categoric distinctions on the basis of tenuous data.

Dayton and Woodburn

Laminated, oriented clay accumulations in the lower horizons of the Dayton and Woodburn profiles are sufficiently alike to encourage the speculation that early pedological history of the two soils might have been similar also. If it is assumed that the clayey horizons in Dayton have developed from formation of secondary clay minerals in place (16, p. 61), the same cause may be postulated for the B horizons in the Woodburn profile.

More favorable topographic position may account for the weaker development of the B horizons in Woodburn. At present, vertical drainage occurs freely in the Woodburn profile, allowing acid leaching to reach at least the outer portion of major peds. Drainage within the Dayton profile is primarily horizontal, above the clay pan, restricting acid leaching to the upper surface of that horizon. Present drainage conditions, therefore, are favorable to destruction of the clay-rich horizons in Woodburn, and to further development of the clay pan in Dayton. Characteristic properties of these two profiles have probably diverged since the time when marked differences in internal drainage occurred.

Similar correlations between horizon sequence and topographic position have been made by Carlisle for the Mardin and Volusia series in New York (3, p. 41). Drawings from microphotographs of his fragipans show silt-covered clay skins bearing a strong resemblance to those herein described from the B horizons of the Woodburn profile. To the extent that this observed similarity is real, one can postulate that the horizons in which these similar pedological features occur have a similar origin.

Amorphous coatings

Clear, pale purple or pale green, isotropic material was observed to occur in all soils examined. Manner of occurrence and amount of these amorphous materials varies widely between soils.

A few silt-size globules of the pale green substance adhere to ped surfaces in upper B horizons of the Astoria, Quillayute and Jory profiles. They are associated with pale yellow, allophane-like material.

In Woodburn, the pale purple material coats some clay skins, but is most abundant in the vicinity of manganese oxide concentrations in the lower B horizons.

Very thin coatings of both the purple and green materials coat some pores in the Walla Walla profile. Correlation between kinds of coating and horizons proved inconclusive.

Isotropic, pale green coats are thicker and more common in the Lookout profile than any of the others. The fact that the isotropic (presumably amorphous) material merges imperceptibly with crystalline clay as the ped wall is approached strongly suggests that the clays are secondary in nature, having crystalized from a colloidal gel. Similar, but thinner coatings, transitional from amorphous to crystalline, occur in the B horizons of the Dayton profile.

There is a distinct possibility that these clear, amorphous coatings have a genetic relationship to crystalline clays wherever they occur. In most of the soils studied here, however, the amorphous layers were too thin to permit valid interpretations.

Conclusion

A knowledge of the arrangement, as well as identification, of constituent components is crucial to understanding the developmental history and present constitution of a soil. Thin sections permit observation of more components, in relatively undisturbed juxtaposition, than other techniques of pedological investigation and therefore afford, perhaps, the most effective single method of determining how soils are put together.

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APPENDIX

Description of Profile

Astoria silt loam

This profile was sampled in Tillamook County, Oregon, on March 26, 1958 by L. H. Robinson and E. G. Knox. The sample site is between the Trask and Wilson Rivers, west of the Trask Cutoff Road on Access Road FB9 to the top of the first big hill and generally south 300 feet on a spur logging road to a high stump above the road on the right and a large (10 feet in diameter) stump and log (with pronounced butt taper) on the left; up the slope about 50 feet from the high stump on the right side of the road; SW 1/4, NE 1/4, sec. 23, T1S, R8W.

The soil is a "Brown Latosol" derived from residuum from soft siltstones, shales, and sandstones.

This location probably receives over 100 inches of rain annually and has average January temperature of about 38°F. and average July temperature of about 60°F.

A_{00} $\frac{1}{2}$-0" Fresh and fermenting litter. Not sampled.

A_{11} 0-6" Very dark brown (10YR 2/3) silt loam (10YR 3/4) dry, strong medium, fine and very fine granular structure, very friable, slightly hard, slightly plastic, slightly sticky, abundant roots, abundant fine and abundant very fine interstitial pores, pH 5.0, upper 2 inches burned, with inclusions of material from lower horizons, lower boundary clear and wavy.

A_{12} 6-14" Very dark brown (10YR 2.5/3) silty clay loam or silt loam (10YR 4/4 dry), strong medium, fine and very fine subangular blocky structure, friable, soft, plastic to slightly plastic, sticky to slightly sticky, abundant roots, few coarse and medium and abundant fine and very fine interstitial pores, pH 5.0, with inclusions of material from adjacent horizons, lower boundary clear and wavy.

B_{21} 14-25" Dark yellowish brown (10YR 3.5/4) silty clay (10YR 5/4 dry), moderate fine and very fine subangular blocky structure, friable, slightly hard, plastic, sticky, abundant roots, few coarse and medium tubular pores, abundant fine and very fine tubular and interstitial pores, abundant very thin surfaces on peds and in pores which may be clay skins, pH 5.0, with inclusions of material from adjacent horizons, lower boundary clear and wavy.

B_{22} 25-35" Dark yellowish brown (10YR 4/4) silty clay (10YR 5.5/4 dry), moderate fine breaking to strong very fine subangular blocky structure, friable, slightly hard, plastic, sticky, abundant roots, few coarse and medium tubular pores, abundant fine and very fine tubular and interstitial pores, abundant thin surfaces on peds and in pores which may be clay skins, pH 5.0, 30% inclusions of material from adjacent horizons especially from below, lower boundary clear and wavy.

B_3 35-50" Yellowish brown (10YR 5/8) silty clay (10YR 6/6) dry, moderate fine subangular blocky structure, friable, slightly hard, plastic, sticky, common roots, few coarse and medium and common fine and very fine tubular pores, abundant thin surfaces on peds and in pores whichmay be clay skins, pH 4.8, 30% inclusions of material from horizon below, lower boundary clear and wavy.

C 50-66" Yellowish brown (10YR 5/6) silty clay (a mixture of 7.5 YR 5/8, 10YR 6/4 and 10YR 7/2 apparently derived from varying rock strata), massive, friable, plastic, sticky, few roots, pH 4.8, common angular pebbles in lower part, lower boundary gradual and wavy.

D_r 66-74-" Light yellowish brown (2.5Y 6/3) with coatings of dark brown (7.5YR 3/4) stratified silt stone, mostly very hard moist consistence, few roots.

Description of Profile

Quillayute silt loam

Climate: (Tillamook station) 94 inches mean annual precipitation. 42°F. mean January temperature. 59°F. mean July temperature.

Location: Sec. 42, T 1S, R 9W, Tillamook County. At county fairgrounds, about 75 feet west of 4H club dormitory, about 12 west from NS fence and about 50 feet south from road fence or line of maple trees south of road (highway Oregon 6 before 1957).

Parent material: Old Silty alluvium on a river terrace.

Classification: Ando-like, Prairie-like

Sampled: Ellis G. Knox and Luther H. Robinson, March 25, 1958.

A_{11} 0-9" Black (10YR 1/1.5) moist, silt loam, strong coarse, medium, fine and very fine subangular blocky breaking to moderate very fine granular structure, friable, slightly plastic, slightly sticky, abundant roots, many fine and very fine interstitial pores, common very fine fairly soft concretions, pH 5.0, lower boundary clear and smooth.

A_{12} 9-24" Black (10YR 1/2) moist, silt loam, moderate medium prismatic breaking to strong medium, fine and very fine subangular blocky breaking to strong very fine granular structure, friable, slightly plastic, slightly sticky, abundant roots, common coarse and medium tubular pores, many fine and very fine interstitial and tubular pores, few very fine fairly soft concretions, pH 5.2, lower boundary clear and irregular.

B_1 24-35" Very dark brown (10YR 2.5/3) moist, silty clay loam, moderate medium and fine breaking to weak very fine subangular blocky structure, friable, plastic, sticky, common roots, few coarse tubular pores, many medium and fine tubular pores, few thin small patchy clay flows, krotovinas of material from horizon above 30% by volume, pH 5.4, lower boundary clear and irregular.

B_{21} 35-46" Dark brown (10YR 4/3) moist, silty clay, very few fine 7.5YR 5/6 mottles moist, weak medium prismatic breaking to moderate medium and fine subangular blocky structure, friable (firmer than above), plastic, sticky, very few roots, few coarse tubular pores, common medium tubular pores, many fine and very fine tubular pores, common thin small patchy clay flows, krotovinas of material from horizon above 30% by volume, pH 5.4, lower boundary clear and wavy.

B_{22} 46-70" Dark yellowish brown (10YR 4/4) moist, silty clay, few fine 7.5YR 5/6 and 10YR 5/3 mottles moist, weak medium prismatic breaking to strong medium and fine angular blocky structure, friable (almost firm), plastic, sticky, very few roots, few coarse and medium tubular pores, many fine and very fine tubular pores, common thin small patchy clay flows, few fine MnO_2 flecks, pH 5.2.

Description of Profile

Jory silty clay loam

The Jory series occur at elevations of 300 to 1000 feet in a climate having a mean annual precipitation of 40 inches with dry cool summers and cool wet winters; an average January temperature of 39.7°F.; an average July temperature of 66.6°F.; mean annual temperature of 53°F.; an average frost free period of 218 days.

Type location: 320 feet west and 150 feet south of access road to Highway 99E, Sunnyside Junction in the SW 1/4, SW 1/4, NE 1/4, Section 25, T 8 S, R 3 W.

A_{1p} 0-6" Dark reddish brown (5YR 3/4) silty clay loam, reddish brown (5YR 4/4) when dry; moderate, fine and very fine granular structure; slightly hard, friable, plastic and sticky; many roots; many medium and fine interstitial pores; few medium iron and manganese-dioxide concretions; medium acid (pH 5.6); abrupt, smooth lower boundary, five to seven inches thick.

A_{12} 6-16" Dark reddish brown (5YR 3/4) silty clay loam; reddish brown (5YR 4/4) when dry; weak, coarse subangular blocky breaking to moderate, fine and very fine granular structure; slightly hard, friable, plastic and sticky; many roots; many medium and fine interstitial pores; few, medium iron and manganese-dioxide concretions; medium acid (pH 5.6); clear, wavy lower boundary, eight to twelve inches thick.

A_3 16-20" Dark reddish brown (5YR 3/4) light silty clay; yellowish red (5YR 4/8) when dry; moderate coarse and medium granular structure; hard, firm, plastic, sticky; many roots; many medium and fine interstitial and tubular pores; thin, patchy clay films; few, medium iron and manganese-dioxide concretions; strongly acid (pH 5.4); clear wavy lower boundary, three to seven inches thick.

B_{21} 21-29" Dark reddish brown (2.5YR 3/4) silty clay, reddish brown (2.5YR 4/4) when dry; strong, medium and fine subangular blocky structure; hard, firm, very plastic and very sticky; few roots; many fine tubular pores; thin, continuous clay films; many, fine iron and manganese-dioxide concentrations; strongly acid (pH 5.3); clear smooth lower boundary; six to ten inches thick.

B_{22} 29-36" Dark reddish brown (2.5YR 3/4) silty clay, reddish brown (2.5YR 4/4) when dry; strong, medium subangular blocky structure; very hard, firm, very plastic and very sticky; no roots many, fine tubular pores; medium, continuous clay films; common, large and medium distinct manganese-dioxide coatings on ped surfaces; many fine iron and manganese-dioxide concretions; strongly acid (pH 5.1); gradual, smooth lower boundary, four to ten inches thick.

B_{23} 36-48" Dark reddish brown (2.5YR 3/4) clay, reddish brown (2.4YR 4/4) when dry; strong, fine subangular blocky structure; very hard, very firm, very plastic and very sticky; many, fine tubular pores; medium, continuous clay films; many, large and medium prominent manganese-dioxide coatings on ped surfaces (50%); strongly acid (pH 5.2); gradual, smooth lower boundary; nine to fifteen inches thick.

B_{24} 48-63" Dark red (2.5YR 3/6) clay, red (2.5YR 4/6) when dry; moderately strong, medium subangular structure; very hard, very firm, very plastic and very sticky; many fine tubular pores; medium continuous clay films; many, medium, prominent manganese-dioxide coatings on ped surfaces (30%); strongly acid (pH 5.3); many feet thick.

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USA

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3-6-60

Description of Profile

Woodburn silt loam

Location: Benton County Oregon. Hyslop Farm. SW 1/4, NE 1/4, sec. 8, T 11 S, R 4 W.

Description: July 7, 1960 by Ellis G. Knox.

Soil Classification: Gray-Brown Podzolic or Prairie

A_p 0-6" Very dark grayish brown (10YR 3/2) silt loam; brown (10YR 5/3) dry; weak, medium and fine, subangular blocky structure; hard to slightly hard, slightly plastic, slightly sticky; many interstitial and tubular pores, lower boundary abrupt and smooth.

A_3 6-13" Dark brown (10YR 3/3) moist, silt loam; weak, medium, prismatic structure; hard, slightly plastic, slightly sticky; common roots; many (30 per sq. in.), very fine, tubular pores, few (2 per sq. in.), fine tubular pores; lower boundary clear and smooth.

B_1 13-21" Dark yellowish brown (10YR 3/4) moist, silt loam; weak coarse, prismatic breaking to weak, coarse, subangular blocky structure; hard, friable, slightly plastic, slightly sticky; common roots; many (40 per sq. in.), very fine tubular pores, few (2 per sq. in.), fine, tubular pores; common, thin clay skins; common degraded ped surfaces; lower boundary clear and wavy.

B_2 21-30" Dark yellowish brown (10YR 3/4) moist, silty clay loam; weak, coarse, prismatic breaking to moderate, coarse, subangular blocky structure; firm, plastic, sticky; common roots; many (20 per sq. in.), very fine, tubular pores; continuous, medium clay skins; few black (MnO_2) ped coatings; lower boundary gradual and wavy.

B_{31} 30-41" Dark brown (10YR 4/3) moist, silty clay loam; few (common along prism faces), fine, distinct mottles; moderate, coarse, prismatic breaking to weak, coarse, subangular blocky structure; firm, plastic, sticky; common roots; common (10 per sq. in.), very fine, tubular pores; common, medium and thick, large clay skins; common black (MnO_2) ped coatings; few degraded ped surfaces; lower boundary gradual and wavy.

B_{32} 41-55" Olive brown (2.5Y 4/3) moist, silt loam; few (common along prism faces), fine, distinct mottles; weak, coarse, prismatic breaking to weak, coarse, subangular blocky structure; firm, slightly plastic, slightly sticky; few roots; common (8 per sq. in.), very fine, tubular pores; common, thin and few, medium and thick clay skins; common black (MnO_2) ped coatings; few degraded ped surfaces; lower boundary gradual.

C 55-108 " (on auger) Dark brown (10YR 4/3) moist; stratified into weak, coarse plates; partly silty clay loam, firm, plastic, sticky, and partly silt loam, friable, slightly plastic, slightly sticky; very few roots; few, very fine, tubular pores; common, thick clay skins in vertical pores; especially in upper part may have very coarse prisms with mottled faces that have few, black (MnO_2) coatings and few clay skins.

Description of Profile

Dayton silt loam

The Dayton soils occur at elevations of 225 to 250 feet above sea level, under a mean annual precipitation of 40 to 45 inches with dry, cool summers and cool moist winters; an average January temperature of 40°F.; an average July temperature of 67°F.; a mean annual temperature of 53°F.; and an average frost free season of 210 days. The Dayton soils are mapped extensively throughout the Willamette Valley area of western Oregon.

Type location: SE 1/4 of SW 1/4 of SW 1/4 of Section 8, T. 13s., R. 4W, Linn County, Oregon. 100 feet north of east and west gravelled road, 1/4 mile east from Peoria, Oregon, Linn County.

A_p 0-7" Light brownish gray (10YR 6/2) silt loam, dark gray (2.5Y 8/1) when moist; weak, fine subangular blocky structure; slightly hard, friable, nonsticky, nonplastic; abundant roots; few, fine, vertical tubular pores; common medium, distinct mottles; medium acid (pH 5.6); clear smooth lower boundary; 5-9 inches thick.

A_{2g} 7-17" Light gray (10YR 7/2) silt loam, grayish brown (2.5Y 5/2) when moist; very weak, fine prismatic apparent in place breaks out to weak fine subangular blocky structure; slightly hard, friable, nonsticky, nonplastic; plentiful roots; common fine vertical and oblique tubular pores and common, medium interstitial pores; common, faint fine mottles; common medium brown and black concretions and few, medium manganese stains; rounded prism tops of B2 peds extend up into A2 showing degraded surface covering of light gray very fine sand 1/8 inch thick; medium acid (pH 5.8) abrupt wavy lower boundary; 8 to 14 inches thick.

B_{2g} 17-35" Light brownish gray (10YR 6/2) clay; dark grayish brown (2.5Y 4/2) moist ped surfaces; crushed grayish brown (2.5Y 5/2); strong, very coarse prismatic structure; very hard, very firm, sticky and plastic; very few very fine roots; very few fine vertical tubular pores; few medium concretions and few medium manganese stains; thick continuous clay films; few slickensides; gradual, smooth lower boundary; 14-22 inches thick.

BC 35-42" Pale brown (10YR 6/3) silty clay, dark grayish brown (2.5Y 5/3); moderate coarse prismatic structure; very hard, very firm, sticky and plastic; no roots; very few fine vertical tubular pores; few fine faint mottles; few medium manganese stains; continuous medium clay films; slightly acid (pH 6.2); clear smooth lower boundary; 5 to 12 inches thick.

C 42-47" Very pale brown (10YR 7/4) silty clay loam, brown (10YR 5/3) when moist; massive with weak suggestion of very coarse prisms; hard, friable, sticky, slightly plastic; no roots; few fine and very fine vertical tubular pores; common fine faint mottles; thick continuous clay flows; slightly acid (pH 6.2).

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USA

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3-8-60

Description of Profile

Walla Walla silt loam

Climate: the average annual precipitation at Moro is 11.13 inches. The average January temperature if 30°F., the average July temperature 69°F. The average frost-free season is 165 days. About 70% of the annual precipitation occurs from October through March. The sample site is probably midway in precipitation between the Moro and Wasco stations. The average annual precipitation at Wasco is 11.86 inches.

Location: SE of SW sec. 25, T. 1 N., R. 16 E., 85 feet west of road curve, 15 feet north of section line, about 4 miles NW of Moro. Sherman County SCD, Sherman County, Oregon.

Parent material: Loess

Description by R. W. Mayko

A_{1p} 0-7" Grayish-brown (10YR 5/2) dry, very dark brown (10YR 2/2) moist, silt loam; weak thin platy breaking to weak fine granular; friable, slightly sticky, slightly plastic; abundant roots, many very fine and fine pores; abrupt wavy boundary.

A_{1pm} 7-8½" Very dark brown (10YR 2/2) moist, silt loam; moderate coarse platy structure; friable to firm, slightly sticky, slightly plastic; abundant roots and moderate number of very fine and fine pores; abrupt wavy boundary.

A_{12} 8½-17" Very dark grayish-brown (10YR 3/2) moist, silt loam; weak coarse prismatic breaking to weak medium subangular blocky structure; very friable, slightly sticky, slightly plastic; abundant roots, many very fine pores; no clay flows; clear wavy boundary.

AC_1 17-25" Very dark grayish-brown (10YR 4/2.5) dry, dark brown (10YR 3/3) moist, silt loam; weak coarse prismatic breaking to weak medium to coarse subangular blocky; very friable, slightly sticky, slightly plastic; abundant roots, many very fine pores; gradual wavy boundary.

AC_2 25-34" Brown (10YR 5/3) dry, dark brown (10YR 4/3) moist, light silt loam; very weak coarse prismatic structure; very friable, slightly sticky, slightly plastic; abundant roots, many very fine pores; gradual wavy boundary.

C_{11} 34-50" Brown (10YR 5/3) dry, dark brown (10YR 3.5/3) moist, light silt loam; very weak coarse prismatic; slightly hard to hard, very friable, very slightly sticky, slightly plastic; abundant roots, many very fine and fine pores; few firm nodules 1/4 to 3/4 inch in diameter; common gray reduction sprinkles throughout the matrix; gradual wavy boundary.

C_{12} 50-66" Brown (10YR 5/3.5) dry, (4/3) moist, light silt loam; very weak coarse prismatic structure; slightly hard to hard, very friable, very slightly sticky, slightly plastic; plentiful roots, many very fine pores; some firm nodules 1/4 to 3/4 inches in diameter; common gray reduction sprinkles throughout the matrix; gradual wavy boundary.

C_{13} 66-76" Dark brown (10YR 3.5/3) moist, light silt loam; massive; very friable, very slightly sticky, very slightly plastic; plentiful roots, many very fine pores; many firm nodules 1/4 to 3/4 inches in diameter; gradual wavy boundary.

C_{ca} 76-106" Brown (10YR 5/3) dry, dark brown (10YR 3.5/3) moist, light silt loam; massive; friable to firm, very slightly sticky, very slightly plastic; some roots, few very fine pores; slightly calcareous with mycelia lime along root channels; many firm nodules 1/4 to 3/4 inches in diameter; gradual wavy boundary.

C_2 106-116" Yellowish-brown (10YR 5/4) moist, very fine sandy loam; massive; very friable, nonsticky, nonplastic; few to no roots, few very fine pores.

Description of Profile

Tolo silt loam

Sampled and described: 8/1/60 by L. T. Alexander, F. Carlisle, R. W. Mayko, G. Lindsay, J. Burr and W. Fergerson.

Location: SW, SW Section 3, T2N, R40E. 50 feet west of center of road, 950 feet south of road intersection, which is on N-S section line, 600 feet along road north of E-W section line fence, Union county, Oregon.

Site position and slope: N40°E aspect. 16% single slope.

Elevation: About 3260 feet.

Climate: Annual precipitation about 24 inches. Elgin, Oregon, about 14 miles southwest of site and perhaps a degree or two warmer has a mean January temperature of 27°F., a mean July temperature of 67°F., a mean annual temperature of 47.3°F., and a mean annual precipitation of 22.21 inches. Less than 10% of the mean annual precipitation occurs through July, August and September.

Parent material: Approximately 2½ feet of volcanic ash overlying old loess-derived buried soil.

Classification: Regosol

Vegetation: Overstory composition is about: 40% ponderosa pine, 30% Douglas fir, and 30% western larch. Site index for ponderosa pine 99, for Douglas fir and western larch 110. Crown canopy is about 60%. Douglas fir reproduction is sparse and brush competition is heavy. The understory consists of 10% grasses, mainly elk sedge and pine grass; 20% forbs, including arnica, strawberry, bracken fern and meadow rue; and 70% brush, including spirea, snowberry, thimbleberry, service berry, willow and rose. The area has been logged and burned 30 or more years ago.

A_{oo} and A_o-2-0" Horizon not sampled. Mainly L layer of pine and fir needles. Slightly decomposed needles ½ inch thick immediately above A_1 horizon.

A_1 0-1" Dark gray (10YR 4/1) silt loam (estimated 6% clay), black (10YR 2/1) when moist; very weak fine granular structure, matted together with fine fibrous roots; root mat tends to give platy cleavage to the horizon; soft, very friable, nonsticky and nonplastic; abundant fine fibrous roots; pores mainly interstitial; numerous white fungal mycelia; common small, 1 to 2 mm charcoal fragments; sample collected contains small amounts of contamination of next lower horizon; pH 6.6; abrupt smooth boundary.

A_3 1-4" Light brownish-gray (10YR 6/2) silt loam (estimated 6% clay), brown (10YR 4/3) when moist; massive with tendency toward very fine granular structure; soft, very friable, nonsticky and nonplastic; abundant fine roots; common fine tubular pores; common small, 1 to 2 mm charcoal fragments; pH 6.2; abrupt smooth boundary.

B or A_{32} 4-7" Pale brown (10YR 6/3) silt loam (estimated 7% clay), brown (10YR 4/3) when moist; massive with tendency toward very fine granular structure; soft, very friable, nonsticky and nonplastic; abundant fine roots; common fine tubular pores; few small, 1 to 2 mm charcoal fragments; pH 6.2; clear smooth boundary.

C_1 7-18" Pale brown (10YR 6/3) silt loam (estimated 7% clay) brown (10YR 4/3) when moist; massive; soft, very friable, nonsticky and nonplastic; plentiful roots; few fine and medium tubular pores, porosity is mainly interstitial pores between sand and silt grains; apparent very low bulk density; pH 6.2; gradula smooth boundary.

C_2 18-27" Pale brown (10YR 6/3) silt loam (estimated 8-9% clay), brown (10YR 4/3) when moist; massive, very slightly hard, very friable, nonsticky and nonplastic; plentiful roots; many fine tubular pores; apparent very low bulk density; pH 6.0; clear smooth boundary.

C_3 27-33" Pale brown (10YR 6/3) silt loam (estimated 10-11% clay), brown (10YR 4/3) when moist; massive with faint expression of the prismatic structure in horizon below carrying across the abrupt boundary; slightly hard, friable, nonsticky and nonplastic; plentiful roots; many fine tubular pores; no clay films; horizon about 60 to 75% volcanic ash and 25 to 40% like lower sequence of horizons; pH 5.9; abrupt (sharp) wavy boundary with a band 2-3 mm wide having clay films at the contact.

B_{1b} 33-37" Brown (10YR 5.4/3) heavy silt loam (estimated 25% clay), dark yellowish brown (10YR 4/4) when moist, with dark brown (10YR 3/3) clay films; weak medium and coarse irregular prismatic and moderate medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; plentiful roots; many fine tubular pores; thin patchy clay films on peds and in pores; white mycelial fungus common on ped faces; some blanched, clean silt coatings on peds; some patches of material similar to horizon above without clay films, but most of the material more like horizons below; pH 6.0; clear slightly wavy boundary.

B_{21b} 37-41" Colors similar to horizon above; light silty clay loam (estimated 30% clay); weak medium and coarse irregular prismatic and moderate medium and fine subangular blocky structure; slightly hard to hard, firm, slightly sticky and slightly plastic; plentiful roots; many fine tubular pores; thin clay films nearly continuous over patches 2 to 3 cm across; white mycelial fungus common onped faces; common, very pale brown (10YR 7/3) dry, dark grayish-brown (10YR 4/2) moist, clean, blanched, discontinuous silt coatings in patches on most peds and in lining of some tubular pores; pH 6.2; gradual smooth boundary.

B_{22b} 41-46" Pale brown (10YR 6/3) light silty clay loam (estimated 28-29% clay), brown (10YR 4/3.5) when moist; weak medium and coarse prismatic and moderate fine and medium subangular blocky structure; hard, firm, slightly sticky and slightly plastic; plentiful roots; many fine and common medium tubular pores; clay films similar to horizon above; blanched silt coatings fimilar to horizon above, but less abundant; pH 6.2; gradual smooth boundary.

B_{23b} 46-51" Colors similar to horizon above; light silty clay loam (estimated 28% clay); weak medium and coarse prismatic and weak medium and fine subangular blocky structure; hard, slightly firm to firm, slightly plastic and slightly sticky; plentiful roots; many fine and common medium tubular pores; distinct patchy clay films on ped faces and in most tubular pores; common, very pale brown (10YR 7/3) dry, dark grayish-brown (10YR 4/2) moist, clean, blanched, discontinuous silt coatings in patches on most peds and in lining of some tubular pores; pH 6.2; gradual smooth boundary.

B_{31b} 51-65" Brown (10YR 5/3) heavy silt loam (estimated 26% clay), (10YR 4/3) when moist with dark brown (10YR 3/3) clay films; weak fine subangular blocky structure; friable to slightly firm, slightly hard to hard, slightly sticky to slightly plastic; plentiful roots; many fine and few medium tubular pores; few patches of continuous clay films, 1 to 2 cm across on a few vertical ped surfaces, but mostly the horizon has thin discontinuous clay films on peds and in fine tubular thin pores; blanched silt coatings similar to horizon above, but fewer and less evident; pH 6.2; gradual smooth boundary.

B_{32b} 65-72" Color, texture, structure and consistence similar to horizon above; plentiful roots; many fine tubular pores; thin discontinuous clay films on peds and in pores; blanched silt coatings similar to horizons above, but least common. Orchard auger boring indicated very similar material extended to at least 80 inches.

Description of Profile

Lookout silt loam

Lookout soils occur at elevations of about 2800 to 3600 feet in a semi-arid climate with a mean annual precipitation of 8 to 12 inches with warm dry summers and cold moist winters. Average January temperature is 26 to 30°F.; average July temperature is 64 to 68°F.; and the frost-free season is 100 to 130 days.

A horizons may be strongly influenced by loess, pumice or volcanic ash.

Type location: NE of NW of SE section 2, T. 6 S., R. 39 E., 200 feet south of the intersection of the road and power line, 75 feet west of the road. Baker area, Union County, Ore.

A_{11} 0-4" Light brownish gray (10YR 5.5/2) stony silt loam, dark grayish brown (10YR 3/2) when moist; weak coarse prismatic breaking to weak coarse subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; abundant roots; many fine interstitial pores; pH 6.4 to 6.8; clear smooth boundary. 1 to 6 inches thick.

A_{12} 4-9" Grayish brown (10YR 5/2) stony silt loam, dark grayish brown (10YR 3/2) when moist; weak coarse prismatic breaking to weak coarse subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; plentiful roots; many fine tubular pores; pH 6.6 to 7.0; clear smooth boundary. 2 to 6 inches thick.

B_1 9-13" Dark brown (10YR 3.5/3) when moist, stony, light silty clay loam, commonly coated light gray (10YR 6/1) when dry with very fine sand or silt that may be volcanic ash; weak medium prismatic breaking readily to moderate fine subangular blocky structure; hard, firm, slightly sticky and slightly plastic; plentiful roots; many fine tubular pores; thick continuous clay films on peds and in pores; pH 7.0 to 7.4; clear smooth boundary. 1 to 10 inches thick.

B_{21} 13-16" Dark grayish brown (10YR 3.5/2) when moist, cobbly silty clay; strong medium to fine prismatic breaking to strong fine blocky structure; very hard, very firm, very sticky, very plastic; plentiful roots; common very fine tubular pores; thick continuous clay films on peds and in pores; pH 7.0 to 7.4; clear smooth boundary. 3 to 6 inches thick.

B_{22} 16-19" Dark brown (10YR 4/3) when moist, cobbly silty clay; strong medium to fine prismatic breaking to strong fine blocky structure; very hard, very firm, very sticky and very plastic; plentiful roots; common very fine tubular pores; thick continuous clay films on peds and in pores, slightly darker brown than interior of peds; pH 7.2 to 7.4; abrupt smooth boundary. 2 to 6 inches thick.

B_{3ca} 19-24" Pale brown (10YR 6/3) silty clay loam, dark brown (10YR 4/3) when moist; moderate, fine subangular blocky structure; hard, firm, sticky, and plastic; few roots; common fine tubular pores; moderately thick nearly continuous clay films on peds and in pores; common segregated and disseminated lime; pH 7.8 to 8.4; clear smooth boundary. 2 to 8 inches thick.

C_{ca} 24-29" Light yellowish brown (10YR 6/4) loam, dark yellowish brown (10YR 4/4) when moist; massive; hard, firm to friable, slightly sticky and slightly plastic; few roots; common fine tubular pores; strongly calcareous with disseminated lime; pH 8.2 to 8.5; abrupt smooth boundary. 0 to 8 inches thick.

C_m 29-45" Very pale brown (10YR 7/3), dark brown (10YR 3/3) when moist, indurated silica-cemented pan containing seams and segregations of lime; extremely firm and extremely hard. The pan has some cemented basaltic cobbles and gravels.

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