GROUNDSURFACES AND SOILS
IN THE WILLAMETTE VALLEY, OREGON

by

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INTRODUCTION

The view that most soils are (a) all of one piece, (b) have reached their observed state of horizon development by differentiation from a more or less uniform parent material, the nature of which may be deduced from an examination of the material beneath the solum, and (c) that they are, or soon will be, in a state of equilibrium with their environment, is widespread (14). That this view is not necessarily correct has been demonstrated very forcibly in the recent work of Ruhe (16) and Butler (8). Butler (8, p. 5) has argued that the occurrence of buried soils "proves the alternation of: (a) a phase of progressive soil development with minimal surface accession," a stable phase, and (b) "a phase of progressive surface accession with minimal soil development," or an unstable phase. From the recurrence of these phases through time, he has developed the concept of the soil cycle (8, p. 6). "This is the sequence of events which commences with the creation of a new surface in the landscape, continues with the development of soils on that surface, and is concluded by the supersession of that soil surface by erosion or burial," the latter coinciding with the unstable phase of the succeeding cycle. The soil cycle may be regarded as
a small scale geologic time unit and has been named a "K cycle" (8, p. 7).

Ruhe has proposed that landscapes are composed of geomorphic surfaces of different age. When these are identified and their age determined, a basis is found for the study of soils occurring on them. On the other hand, Butler has proposed that landscapes are composed of ground-surfaces of different age. These may be identified, up to a point, in the same way as geomorphic surfaces, by landscape analysis. The point of departure between the two concepts, though there is a strong analogy between them, is that the groundsurface is identified finally by continuity of a "unit mantle of soils" (8, p. 9). "The groundsurface is .... the materials, soils, and surfaces relating to one K cycle." Thus it is possible that a groundsurface may encompass more than one geomorphic surface in particular circumstances.

These ideas are, however, still very novel and are regarded by many as applicable only in the rather "peculiar" and even "abnormal" environment in which the work was done. On the other hand no one will deny that the formation of soils has been interrupted from time to time by burial or complete or partial removal of the solum in regions subjected to Pleistocene glacial or periglacial conditions or in stream valleys. If the concepts of periodicity in landscape phenomena and cyclic soil development
proposed by Butler (8) do have more general validity, this will be of great significance in studies in soil genesis, in soil classification, and in soil survey and correlation.

It has therefore been considered timely to see if these novel concepts of soil and landscape development can be applied effectively in western Oregon, specifically in the area of the Willamette Valley and its sideslopes. This is a very important region agriculturally, and one in which more than one anomaly in the interpretation of soil character and occurrence has become apparent in recent years.
THE STUDY AREA

The Willamette Valley and its sideslopes include much of the most productive agricultural land in the state of Oregon. The valley is a structural depression lying between the Cascade and Coast Ranges and extending from Eugene to Portland, which has been filled with sediments, dominantly of medium to fine texture. Gravel deposits occur around the margins and thrust out into the valley and are especially prominent east of the Willamette River. The valley is broken in its northern half by hills of moderate relief separating broad alluvial flats. Such topographic features are indicated by locality names such as the Portland Basin, Portland or Tualatin Hills, Tualatin Valley, Chehalem Mountains, Yamhill Valley, Red Hills of Dundee, Dayton Prairie, French Prairie, Eola Hills, Salem Hills and Waldo Hills. Hardscrabble Hill, Knox Butte, Hungry Hill, Peterson Butte and Powell Hills are prominent high points rising abruptly in a sea of alluvium in the southern half of the valley between Salem and Eugene.

The valley is separated naturally into a northern and a southern half by the Eola, Salem and Waldo Hills. The Willamette River passes between the Eola and Salem Hills through a gap which at its narrowest point is a little less than 1½ miles wide. From Eugene to Albany, a distance of 40 miles, the plain is from 9 to 20 miles...
wide and descends in elevation from 360 to 450 feet at Eugene to 225 to 300 feet at Albany, at an average gradient of about 3.5 feet per mile. From Eugene to Junction City and thence east of the river as far as the Salem Hills, the valley floor is formed by a succession of broad, coalescing alluvial fans from the mountain valleys to the east, covered by a thin veneer of silts, with a surface slope to the west from 6 to 11 feet per mile. Each fan is traversed by numerous faintly marked distributary channels (16, p. 10). Between the fans, west of the Willamette River north of Junction City, and generally along the western margin of the valley, the plain is built up by smooth-surfaced silts, sloping northward by as little as 2 feet per mile.

Between Albany and Salem, the valley plain is constricted sharply by outlying hills to widths of two to four miles in two locations: between Spring Hill and Hard-scrabble Hill just north of Albany and at American Bottom between Oak Hill and Prospect Hill 8 miles to the north.

North of Salem, the valley widens abruptly to a plain 9 to 25 miles wide, whose northern margin is formed by the Chehalem and Tualatin Hills. This section of the valley includes several extensive and strikingly flat "prairies." The plain descends in elevation from about 200 feet near Salem, and 190 feet near Canby, to about 150 feet near McMinnville, in a northwesterly direction across the general northerly course of the Willamette River, again suggesting
the influence of possible outwash fans from the Cascades. Piper (16, p. 10) thought that the surface form of this northern segment of the plain was clearly not a product of ordinary stream aggradation. Continuous with the main valley plain are the lobes north and south of McMinnvile occupied by the north and south forks of the Yamhill River.

The next major lowland area to the north is the Tualatin Valley. This is separated from the main valley by low divides through the Chehalem Mountains. The valley is made up of two dissimilar parts in the region of present interest. From the foothills of the Coast Range in the vicinity of North Plains and Banks the river traverses an extensive lowland plain topographically analogous to that of the Willamette Valley proper. But southeast of Tualatin the river enters a deep and narrow valley by means of which it reaches the Willamette River just southwest of Oregon City.

The present day streams of the Willamette Valley in general flow within inner valleys cut below the main lowland plain. These inner valleys are usually floored with younger alluvium, forming some of the most fertile agricultural lands in the whole valley. Meander scars are still very noticeable, giving rise to a gently undulating surface with oxbow lakes and overflow channels. Between Eugene and Newberg the inner valley of the Willamette River ranges between 0.5 and 1/2 miles in width. From Eugene
to Albany its floor slopes concordantly with the main plain, from 5 to 15 feet lower in elevation (16, p. 11). Farther north the grade increases and the trench deepens gradually until near Newberg it is some 80 feet below the surface of the plain proper. Downstream from Newberg the trench narrows to form a narrow rock-walled gorge from near Canby to Oregon City, where the river descends into the Portland Basin over Willamette Falls.

The larger tributaries of the Willamette River occupy similar trenches within the main lowland. One trench running northeast from the Willamette River near Salem to the Pudding River near Mount Angel is not occupied by a present day stream. It is notably shallower than either of the two trenches that it connects and is thought by Piper (16, p. 12) to have been occupied by an ancestral Willamette River in a fairly early phase of entrenchment below the main valley plain.

Several high level gravel terraces or fan aprons extend westward into the valley from side valleys draining the Cascade Range. These terraces can be traced upstream and evidently are related to former more extensive glacial outwash deposits in this area (2). Those associated with the South Santiam River have been mapped and described in some detail in the Albany and Lebanon quadrangles (3, 4). A remnantal high level gravel terrace is
also found at different places on the western fringes of the valley.

Within the foothills of the Coast Range on the west, sedimentary rocks of lower Tertiary age are dominant. They are mainly arkosic wacke sandstones typified by the middle Eocene Tyee formation (6). There are also numerous occurrences of basic igneous rocks, such as the Stayton lavas (21) in the Salem Hills area, and the Columbia River basalt in the Portland Hills (27).

Originally a surface of low relief, the Coast Range has been elevated and dissected relatively recently to give the present mountainous topography. Above a general crest level of only about 1500 feet stand several isolated peaks. The passes are lower. There is a gentle eastward slope terminating in the belt of foothills adjoining the lowland.

The foothills of the Cascade Range rise gradually from the west and exhibit a relief equal to or exceeding that of the Coast Range. The broad crest of the range is between 4,000 and 5,000 feet and forms the platform from which rise a spectacular series of volcanoes, with permanent snow and alpine glaciers. Thayer (21) has mapped Oligocene Illahe formation and Miocene Stayton lavas in the Salem Hills, and these formations are joined by Miocene Fern Ridge tuffs in the Stayton area. In the area east
and south of Portland Treasher (25) has recorded Columbia River basalt, Pliocene Troutdale formation and Plio-
Pleistocene Boring lava.
FIELD METHODS

Nearly all state highways and county roads in the hills and in areas of dissected fan and terrace formations, as well as a high proportion of those in the lowlands, were traversed. Field notes of soil morphology and stratigraphy were made at each roadcut encountered, special note being taken of cuts revealing cross-sections normal to the axis of drainage divides. The nature and relation of bedrock to the present day surface as well as the depth of unconsolidated material and the visual state of weathering of the bedrock were noted. Many line drawings were made in the field to record the relationships observed. During this phase of the work, which was largely completed during the summer of 1959 after preliminary inspections in 1958, some 700 individual sites were described. Detailed descriptions of 25 sites, spaced through the area and individually embodying the elements of proof, were made in the summer of 1960. These sites are shown on the accompanying map (Fig. 1).

In examination of vertical sections of soil material, special note was taken of those features suggestive of discontinuities other than horizon boundaries. Landscape and soil characteristics related to erosion and/or burial of former soils followed by development of new soils on the fresh surfaces thus created have been described by
Figure 1. Location of description sites
Ruhe (17, 18) and Butler (8). These features include such phenomena as (a) stone lines, (b) truncation of soil horizons, (c) superposition of soil materials of greatly different character each having internal homogeneity, (d) cut and fill cycles in side valley alluvial deposits, and (e) lateral continuity and homogeneity of soil materials overlying heterogeneous substrates which may include other soil materials or more or less weathered bedrock.

Most discontinuities between geological materials do not mark boundaries between soils of different age. Soil development commonly takes place across such boundaries, and the soils of one groundsurface may run the gamut of variation in parent material and profile development in so far as this may be controlled by extreme characteristics of the parent material. It is only when the soil layers, and/or the associated weathered zone, show evidence of erosion and/or burial, that this may be used as evidence for the separation of groundsurfaces and soils of different age.
Specific Field Locations

1. **Jackson Hill.** In the SE 1/4, sec. 35, T. 8 S; R. 3 W; Salem quadrangle, a portion of the old Pacific Highway, now an access road to U. S. 99, skirts the eastern slope of a local eminence known as Jackson Hill. A cut almost transverse to the axis of a southeast trending spur was made in locating the present roadbed. The materials revealed in the cutting and their stratigraphic relationship are shown schematically in Figure 2. The site is within a large area of Miocene Stayton lavas (21) now correlated with the Columbia River basalt (6).

On the soil map (23) the soils of the area are mapped as Aiken series.

As indicated in the diagram the B2 and B3 horizons (Y) are not continuous over the crest of the spur but pinch out between weathered bedrock (Z), which rises in the section, and the A and B1 horizons (X), which are continuous though of reduced thickness over the crest. A thin line of hard cobbles occurs near the lower boundary of the B1 horizon. The cobbles are dominantly of basalt with only a thin weathering rind, but bauxitic cobbles are not infrequent. Toward the interflue, which is at an elevation of 550 feet, the cobbles become more frequent and
Figure 2. Jackson Hill. location 1, schematic cross-section
of larger size, until over the crest they form a stony layer between the A-B1 material and the underlying weathered basalt. Occasional boulders occur. The angularity and relatively little weathered condition of the cobbles and boulders contrasts sharply with the extreme weathering of the bedrock, in which only scattered hard rock cores occur in a spheroidal weathering pattern.

A distinct break in slope is evident in the axial profile of the interfluve at an elevation of about 650 feet. This is marked by an outcrop of hard basalt at this point. Above a bevel extending upslope to about 700 feet, there is an upland of gentle relief rising gradually to a maximum elevation of 750 feet.

The layer of cobbles and boulders is a lag gravel recording an erosion cycle which cut into a former surface, more or less preserved in the upland above the bevel. Accompanying this was truncation and removal of a soil that had developed during a long period of groundsurface stability (8). Much of the material was deposited as colluvium downslope from its point of removal. The A and B1 horizons have developed in this material. The relationships observed in the cutting are representative of those observed generally in the Salem Hills. The evidence points to an unconformity separating two parts of what has been commonly regarded as a normal soil profile, with genetically related horizons, developed from parent material whose character
would be deduced from the nature of the underlying weathered basalt.

As implied in the designation of the soil materials as horizons in a unit soil profile, there is a marked difference in organization between the upper and lower materials. The major differences are in aggregation, porosity, and development of cutans (7). Accessory differences in color and segregations such as manganese oxide coatings are also striking. The lower and therefore older\(^1\) soil material has a strongly developed fine angular blocky and/or parallelipipedal structure and even the smallest peds are coated with thick, continuous cutans. Its visual porosity is much lower than that of the upper soil material. It is usually a strong reddish brown in color. The upper and therefore younger soil material has only thin, discontinuous cutans, or none, is more earthy, with weaker structural development, and is usually brown or gray in color.

2. Bellfountain Road. Immediately south of the entrance to the Foltz farm on the Bellfountain Road just east of the section line between sec. 19 and sec. 20, T. 13 S., R. 5 W; Monroe quadrangle, there is a shallow roadcut

\(^1\)Age in this context refers to the age of the stratum, which may or may not be coincident with the weathering age of its components.
on the west side of the road. The section (Figure 3) traverses a boundary shown on the soil map between soils of the Aiken and Melbourne series (9).

At point 1 (elevation 425 feet) the sequence of horizons includes A, B1, and B2 which appear to be genetically related. From point 2 there is a sharp break in slope and between points 2 and 3 the B2 and part of the B3 horizon is bevelled out. The A and B1 horizons are continuous (X), though diminished in thickness by about one third, and from point 3 to 4 they directly overlie the truncated B3 horizon. At point 3, a basal horizon of well-weathered and rounded water-worn gravel appears (Zg) and borings show that it is present beneath the profile at point 1. Between points 3 and 4, the A-B1 material very nearly recovers its observed thickness at point 1. Through this latter interval it overlies mottled B3 horizon material, with red clay coatings and fillings in a yellow matrix, though the A-B1 material is brown in color. South of point 4 there is a small side valley which extends upslope to the northwest. It crosses the main slope at about a 45 degree angle. The A-B1 material is thicker as it crosses the side valley but the B3 horizon is absent. The A-B1 material now overlies shale (Zs) which rises in the section downslope. At the break in slope to the main drainage about one-quarter mile south, the shale bedrock is overlain by less than six inches of stony soil material.
Figure 3. Foltz Farm, location 2, schematic section
No lag gravel has been noted in this section. Nevertheless there is an erosional unconformity between the A-B1 material and the various materials beneath it. As pointed out by Butler (8, p. 13) "the separateness of a soil layer can be proved by tracing its continuity over a diversity of substrates. Because of the diversity and discontinuity of the substrates vis-a-vis the relative uniformity and continuity of the soil layer, none of the substrates can be part of it. The specific layer is that part of the several vertical assemblages which is common to all."

It is then concluded that an apparently normal soil profile, such as at point 1, actually contains an older soil material represented by the B2 and B3 horizons, overlain by a younger colluvial material within which are the present A and B1 horizons. The younger soil material differs from the older morphologically to a degree that is strikingly comparable to the situation at Jackson Hill.

3. Tallman Loop. In NE ½, NE ¼, sec. 15, T. 11 S; R. 5 W; Corvallis quadrangle, recent widening operations on the Tallman Loop road have left a long cutting on the west side of the road across a broad east trending spur at an elevation of about 325 feet. The cutting is within an area shown as Melbourne clay loam on the soil map (9), with boundaries to Aiken silty clay loam, Olympic clay shallow phase, and Olympic clay loam within one-quarter
mile to the southwest, west, and north respectively. The cutting is about 225 yards in length (Figure 4).

Bedrock rises almost to the surface at point 1, where there is an accumulation of hard cobbles in a thin soil mantle. The mantle increases in thickness downslope to the north and south. The cross-section is asymmetrical, with a longer and more gentle south slope from the axis. Occasional hard cobbles occur at or slightly above the interface between strongly weathered bedrock and the soil material. The cobbles increase in frequency at the south end of the cut where the slope steepens to an easterly drainage. Soil material different from the weathered bedrock and the surface soil material occurs in discontinuous thin lenses, and at point 2 it fills a break in the weathered bedrock. This break is thought to represent a former erosion gully.

A joint pattern, marked by even more strongly weathered material, is evident in the thoroughly weathered bedrock. Joints with a more or less vertical orientation in the cut face are truncated at the interfaces between bedrock and both of the soil materials seen in the section. Although only occasional cobbles occur within the soil material near the interface, none at all were noted within the bedrock. Only at point 1 does hard bedrock occur within the section. Though infrequent, the cobbles are significant and together with the abruptly and smoothly
Figure 4. Tallman Loop, location 3, schematic cross-section
terminated joint pattern indicate an unconformity between the soil material and the weathered bedrock. An old soil, represented by the fill material at 2 and the thin lenses elsewhere in the section, was almost completely removed during a period of erosion. The major part of the present soil mantle exposed in the cut is therefore depositional on the underlying, weathered bedrock.

Moreover, the old soil itself does not appear to have formed in place from the underlying material. The gap in the bedrock at 2 and the clear boundary between bedrock and supposed fill which is continuous with the old soil, points to an erosion cycle prior to development of the old soil. This conclusion is further supported by the occurrence of a stone line beneath a lens of old soil material from point 3 to point 4.

As at the two sites previously described, the younger soil material can be distinguished from the older by morphological criteria which include color, structure, cutan development, porosity, and segregations. There is a general similarity in degree of expression of characteristics of the older soil material at all three sites so far considered. There is also a general similarity of the younger soil material. This situation will receive greater emphasis as more sites are described. It is suggested that the difference in degree of soil development between the two groups is large, and that there is a smaller range of variation
within each group. This state of affairs was so evident after the first few weeks of field work that it was adopted as the basis for a working hypothesis. According to this hypothesis, the different groups are regarded as representing separate and distinct soil systems. Within each soil system there is, at its given level of development (basically determined by the time factor) a wide range of variation of each soil property determined by the other soil forming factors. This is true because such a separation between soil systems involves no essential restriction in the operation of the factors generally regarded as effective in soil formation, other than in their period of operation, that is, in the time factor.

The two soil systems thus far tentatively identified were designated X and Y. Z is the substrate, whether C or R, and whether this is older than Y or not. This device was adopted for easier recording of repetitive observations in cases where materials appeared to belong to one soil system or the other.

4. Spring Hill. In the SE $\frac{1}{4}$, NE $\frac{1}{4}$, SW $\frac{1}{4}$, sec. 26, T. 10 S; R. 4 W; Albany quadrangle, the county road traverses the summit ridge of Spring Hill at an elevation of 475 feet. The ridge rises in an east northeast direction to a maximum of 519 feet within a one-quarter mile. Since the road is here oriented north and south, the cutting
through which it passes is not exactly normal to the longitudinal axis of the ridge. On the soil map (9) the upland is shown as Melbourne clay loam, friable phase. The bedrock is level-bedded, soft, weathered, upper Eocene arkosic sandstone, comparable to the upper Eocene Spencer formation (6). Since the ridge is falling away steeply to the west southwest, there is a large exposure of soil and bedrock in a cut on the east side of the road (Figure 5).

The greater part of the soil mantle has a moderate degree of organization with clear to gradual boundaries between horizons. The B2 horizon is reddish brown, friable, sandy clay loam, with moderate, fine to medium, subangular blocky structure, and porous, with thin, discontinuous cutans. The boundary to bedrock is abrupt. The thickness of this soil material is quite uniform at about 30 inches on the north slope and over the crest, but decreases sharply to 9 inches at point 3 on the upper south slope, increasing again in thickness lower down. From point 1 to point 2, a thin horizon of red-brown clay occurs. It is intermingled with yellowish brown sandy material similar to the underlying bedrock, to which it has a gradual boundary. The clay is rather dense and has strong, fine, angular blocky structure, with black manganese coatings, and thick, continuous cutans on ped surfaces. Tongues of this material penetrate deeply within the bedrock. Similar tongues are observed beyond the lateral
Figure 5. Spring Hill, location 4, schematic cross-section
limits of the horizon, but owing to more complete truncation downslope they are not seen at point 3. The boundary between this clay horizon and the rest of the soil mantle is abrupt.

This abrupt boundary, between the reddish brown, friable soil material and the underlying bedrock on the one hand, and the red-brown clay on the other, marks an unconformity. The red-brown clay is the remnant of a former soil which was removed completely from the ridge slopes as seen in this section. The morphology of the materials and their stratigraphic relationship is compatible with the hypothesis that the surface soil represents the X soil system and that the remnantal clay horizon represents the Y soil system. The Y soil may have developed in situ from material similar in nature to the bedrock, Z.

5. Orchard Knob. North of Dallas, the Orchard Knob road runs over the highland, linking James Howe road and state highway 22. In SW 1/4, NW 1/4, sec. 17, T. 7 S; R. 5 W; Dallas quadrangle, it crosses a series of small upland valleys and interfluves descending steeply to the northeast. Cuttings on the southwest or upslope side of the road at an elevation of 750 feet, reveal the soil and bedrock arrangement shown in Figure 6. The geological map of the quadrangle (5) shows middle Eocene sediments of the Umpqua-Tyee series and an inlier of Siletz River volcanic
Figure 6. Orchard Knob, location 5, schematic section
series, the latter outcropping to the north and east of the site. According to the soil map (24) the site is partly within a peninsula of Olympic silty clay loam with boundaries to Melbourne silty clay loam, reddish phase. The section extends across a soil boundary marked by the appearance of basic igneous rock (basalt?) cobbles at point 3.

Two kinds of soil material were noted in the section. One is brown, friable and porous, with clear to gradual horizon boundaries, and minimal development of cutans on ped surfaces. The other is bright brownish-red, and firm, with strong, fine, angular blocky structure, well-developed clay cutans on ped surfaces, and few pores. This material has been regarded as the B2 and lower horizons of the Melbourne silty clay loam, reddish phase, profile. The boundary between these two soil materials is abrupt. The upper material thickens on the slopes of the interfluve and across the side valley, and is thinnest on the crests of interfluves 1 and 2. In the section of interfluve 2, argillaceous bedrock passes to soil material via a diffuse upper boundary. At point 3 the upper soil material becomes cobbly but retains its other features. The cobbles are not derived from the underlying sedimentary bedrock and must have been moved from outcropping Siletz River basalt at a higher elevation.

A former soil represented by the red clay was partially removed during an erosion cycle. This cycle was
responsible for deposition of the colluvial material in which the upper soil horizons have since developed, as well as for leaving the accumulation of cobbles as a lag gravel. There is thus an unconformity between two soil materials, which in superposition constitute the Melbourne silty clay loam, reddish phase, profile. Their morphological features are consistent with their inclusion in the X and Y soil systems respectively. With complete removal of Y soil material and introduction of basalt cobbles within the X material, as at point 3, the soil is classified as Olympic silty clay loam.

6. Willamina. North of Willamina, Willamina Creek is deeply incised. Its tributaries, draining the uplands to the east, descend through gorge-like side valleys. The available relief is of the order of six to seven hundred feet. About six miles north of Willamina, the Willamina Creek road and the Rock Creek road, along the next major drainage to the east, are joined by a short cross road which leaves Willamina Creek road at an elevation of about 350 feet, and rises to 600 feet within three-quarters of a mile. East of the latter point the soil map shows Sites clay occupying a gently sloping upland (12).

In SE 1/4, sec. 12, T. 5 S; R. 6 W; Sheridan quadrangle, about 0.35 miles east of Willamina Creek road within an area mapped as Melbourne clay, there is a cutting on the
south side of the road which transects a steeply descending spur whose core is a basic igneous dike rock. The stratigraphic arrangement of the mantle materials is asymmetrical in a plane normal to the axis of the spur. On either side of the hard core there is deeply weathered brownish-red sedimentary rock. Near the top of the hard rock core on its east side is a small pocket of brownish-red clay having Y morphology. The surficial material is a dull reddish-brown silty clay loam which overlies, in turn from east to west, deeply weathered sedimentary rock, Y soil material, hard basaltic rock, and deeply weathered sedimentary rock. This material is thinner over the crest of the spur and thickens downslope to either side. On the western slope the material is markedly cobbly in the lower part and the cobbly horizon increases in thickness downslope. The morphology of this surficial layer requires its inclusion in the X soil system.

About 0.4 miles east of the section just described, a cutting on the north side of the road at an elevation of about 500 feet reveals sedimentary bedrock, bright brownish-red clay lensing out downslope, and brown silty clay loam as a continuous surface layer. This site is close to a boundary between normal Sites clay and an area of the same series hachured to denote its rough topography.

Sites clay is characterized by its thick, red, clay B2 horizon. This material is dense, has a strong grade of
fine angular blocky structure and well developed clay cutans continuous on the ped surfaces. The B3 horizon material is little different except for coarser and weaker structure. These are the most characteristic features of Y soil materials and of Y soils developed from medium to fine textured parent materials with a high clay content or clay-forming potential. The horizons above the B2 in the Sites profile are rather similar in character to materials assigned to the X soil system. It is not proposed in all cases that such an upper material is depositional on the B2 and lower horizons. Since these features are observed over extensive uplands of gentle topography, a depositional origin would be difficult to substantiate. Some other factor or factors may be responsible for this similarity of the upper horizons of what are clearly older Y soils with materials proved to be depositional and unconformable on various substrates in other topographic positions but which have been assigned to the younger X soil system.

In both of the sections described above an unconformity between the X soil material and the various substrates is evident. Sites clay is the relatively undisturbed Y soil. Where X material overlies weathered sedimentary rock, the soil profile has been designated Melbourne clay. There are thus two soil systems represented in this locality. Their morphological distinctness is thought to be a consequence, primarily, of a considerable difference
in the time factor. The Y soil system is regarded as having developed during a considerably longer period of groundsurface stability than the X soil system. Depending on the magnitude of this probable time differential, variation in other soil forming factors, notably climate, may also be effective.

7. McMinnville. In the southern half of sec. 12, T. 4 S; R. 5 W; McMinnville quadrangle, the county road skirts a natural amphitheater in the hills opening to the southwest. Steep slopes surround a deep valley as if a scoop had been removed from a hill of ice cream. There is a cutting on the northwest side of the road in NE ¼, SW ¼, sec. 1, at an elevation of 425 feet. On the soil map the site appears within a large area of Aiken clay loam which is the soil series mapped on uplands underlain by basic igneous rock (12). About one hundred yards downslope there is a boundary to Olympic clay loam, a soil mapped on lower slopes in the same terrain. The cutting is normal to the axis of a broad interfluve sloping steeply to the southeast.

The section shows a well defined stone line separating two soil materials. The lower soil material is separated from strongly weathered bedrock, in which rounded hard rock cores are noticeable, by a diffuse lower boundary. The upper boundary is marked by the stone line and is clear.
The material above the stone line varies in thickness from three to five feet across the section. It is relatively cobbles free. It is thinnest and stoniest over the crest of the interfluve. The material is dark reddish-brown silt loam to silty clay loam, with weak very coarse prisms, breaking to moderate fine subangular blocks. It is very porous, with common, large, cylindrical pores with organic interior coatings, and filled with organic debris. Cutans are weakly developed or absent in the B1 horizon. Small inclusions of material similar to that below the stone line are found in the lower one-third of this layer.

The B2 horizon below the stone line is brownish-red, dense, silty clay, with moderate coarse and fine prisms breaking to very fine prisms and fine angular blocks. Well developed cutans are continuous on the surfaces of the smallest peds. There is a coarsening of structure with depth. In the lower part of the B3 horizon tongues of this material extend into the weathered bedrock. Red cutans coat reddish yellow material having common medium and fine cylindrical pores.

The stone line represents a lag gravel and marks an unconformity between material of an X soil above and a truncated Y soil below. The Aiken clay loam in this area is thus a composite soil with the upper horizons formed in colluvium deposited on the lower horizons of a pre-existing soil, the upper horizons of which were removed
earlier in the same erosion cycle. Olympic silty clay loam is developed in deep, cobbly colluvium, with remnantal Y soil material, if present, well below the solum, or in shallower, cobbly colluvium over bedrock.

8. Yamhill. About 1.4 miles in a direct line south-east of the intersection of state highways 47 and 240, there is a short connecting road running due east and west. The location is NW 1/4, NE 1/4, sec. 10, T. 3 S; R. 4 W; Yamhill quadrangle. North of the road the slope is moderate and convex upwards. South of the road the slope falls away steeply into a side valley which heads up in a north-easterly direction until cut by the road. North of the road it is shallow and alluviated. A shallow cutting on the north side of the road was examined over a distance of more than three hundred yards east from the western intersection with a north-south road from an elevation of 300 to 350 feet. The conformation of bedrock, an argillaceous sandstone of Oligocene age (27) and overlying unconsolidated materials is shown in Figure 7.

There is a break in the exposure of bedrock across the side valley and the succession of materials above bedrock is different from point 1 to point 2 than from point 3 to point 4. To the west of this break bedrock rises in the section to a position only 10 inches below the surface before again falling away. Above bedrock two major horizons
Figure 7. Yamhill, location 8, schematic section
are evident, only one of which is continuous over the cresting bedrock. The other is pinched out on the east and reappears, downslope relative to the bedrock surface, west of the crest.

The continuous horizon is of variable depth from ten to thirty inches, but is uniform in texture and morphology. It is a light grayish brown silt loam. Its structure and fabric strongly reflect the activity of soil fauna. Rounded tubular casts are prominent in a fine, porous, crumb structure. There are many coarse, medium, and fine tubular pores, many of which have coprophilous fillings. Cutans are absent but organic coatings are common lining the larger pore surfaces. The lower boundary is clear to underlying soil material but abrupt where this horizon sits upon bedrock.

The discontinuous horizon varies in depth from nine to seventeen inches. It consists of coarse prisms of gray brown silty clay loam. Cutans are well developed on the surfaces of prisms with dominantly vertical orientation. The interior of the prisms is apedal, with brittle consistence, and many fine and very fine tubular pores lined with cutans.

The continuous soil material extends across the side valley but decreases in thickness on the valley slope to the east. It is here underlain by a brown silty clay loam with weak coarse prismatic structure breaking to medium
and fine prisms of brittle consistence. Thin, discontinuous cutans in the upper few inches are thicker and more continuous on the vertically oriented surfaces of large peds at greater depth. Fine interstitial, and medium and coarse tubular pores are common, the latter frequently filled with organic debris. There are occasional rock fragments. The upper boundary of this material is clear and smooth. The lower boundary is abrupt and irregular. Small inclusions of bright reddish brown clay are found within the horizon and its color is reddish brown where it overlies a lens of this material from point 4 to point 5.

From point 4 to point 5 there is a lens of bright reddish brown clay loam with weak coarse prismatic structure and well developed cutans. There are few, coarse, tubular pores. These are occasionally filled with red clay while others are filled with organic debris. Rock fragments are common within peds and there is much visible muscovite mica. The maximum thickness of the material is less than twelve inches but tongues of red clay extend downwards in cracks in the bedrock and bedrock cores are coated with red cutans. From a bright reddish yellow with red clay tongues, the bedrock becomes light gray with rusty streaks and no clay tongues with depth. This is how it appears in the rest of the section, suggesting some removal by erosion.
There appear to be three distinct materials above bedrock in this section. The first of these is the lens of material above bedrock (Y) between point 4 and 5. This is regarded as the remnant of a former Y soil, probably part of the B3 horizon. There was evidently sufficient time during this phase of soil formation for bedrock to become fully integrated with the soil profile. Nowhere else in the section does bedrock appear as other than a II R horizon (26, p. 28). Two materials represent a second phase of soil formation which took place after the erosion cycle which removed the greater part of the Y soil and some of the bedrock. These are the discontinuous soil materials in the section (X). Though somewhat different in character, these two materials represent the X soil system. The time from the placement of this material up to the present has evidently been insufficient for the development of visible evidence of the effect of soil forming processes on the underlying bedrock. This suggests that a much longer period of virtual ground surface stability is implied in the degree of development associated with the Y soil system, and that the greater part of this development took place before the advent of the erosion cycle terminating such a stable period.

There is evidence in this locality for an erosion cycle following X soil development. The upper material in the section is morphologically uniform and distinct in
character. It is continuous over a variety of substrate materials of diverse character, though it does tend to lose its identity between points 3 and 5 as it becomes thinner and appears as a genetic A horizon over X soil material. Nevertheless there is adequate basis for its separation as a depositional material resulting from erosion of the former X groundsurface. It is therefore considered to represent a W soil system. Very little visual soil development is apparent in the material. The period during which it has formed a stable ground surface has evidently been of much shorter duration than that represented in the degree of X soil development. It has not been recognized in earlier sections. This is not to say that the groundsurface in these other areas was necessarily left undisturbed during the implicit W erosion cycle. But it does mean that criteria for its recognition in these areas are either absent or the subtlety of their expression escapes the comprehension of this observer.

On the soil map this area is included in a large expanse of Melbourne loam (12). On the basis of the presence or absence of the separate materials identified in this section, at least four distinct soil profiles may be described.
9. **Parrett Mountain.** On the south side of the road in NE ½, sec. 13, T. 3 S; R. 2 W; as it descends the steep northwest slope of Parrett Mountain toward Rex, a roadcut across a spur reveals the sequence of materials shown in Figure 8. Bedrock in this area is Miocene Columbia River lavas and associated intrusives (28). The soil is mapped as Olympic clay loam (12). Loess of varying thickness mantles the surface at the site which is located near its identifiable southern limit (22).

The loess (Xl) overlies two materials which are distinct from each other and from the loess. One is a deposit of cobbly, brown colluvium (Xc). The other is dark reddish brown clay (Y). In section the clay forms two interfluvres, with colluvium filling the space between them beneath the loess. The interfluve on the right of the figure has a weathered rock core below relatively stone-free clay. Where the loess is thickest (about six feet) a soil of moderate development is found wholly within it. The underlying colluvium does not show much soil development and it seems therefore that little or no soil development took place in it prior to burial by loess. One concludes from this that colluviation may have been closely antecedent to loess deposition, and that the two materials reflect different phases of the same period of groundsurface instability. On the other hand, the red clay shows a high degree of soil development and is correlatable
Figure 8. Parrett Mountain, location 9, schematic section
on the basis of its morphology with the lower B2 and B3 horizons of a Y soil, which appears to have been truncated prior to burial. Again, the stage of development shown in the red clay was evidently reached during a long period of groundsurface stability prior to the unstable phase recorded by the presence of colluvium and loess.

Though loess is commonly found on uplands and north slopes in the Chehalem Mountains overlying red clay which appears to be derived from basaltic materials, evidence of colluviation antecedent to the deposition of loess is rarely seen. The loess itself commonly appears to have been colluviated. A situation similar to that described above was noted in two other places along the same road: near the boundary between the NW ¼ and NE ¼ of the adjoining sec. 14. Loess over red clay may be seen also in a roadcut on state highway 219 in SE ¼, sec. 29, T. 2 S; R. 2 W; (22, p. 10) and in NW ¼, NW ¼, sec. 27, T. 2 S; R. 2 W.

10. **Skyline.** In the NE ¼, SW ¼, sec. 34, T. 3 N; R. 2 W; a cut on the northwest side of the road reveals the sequence of materials shown in Figure 9. There is a steep southeast slope below the road. Above the cut the slope is moderate and convex to the crest of a primary interfluvue at an elevation of 1550 feet between north and south drainage. The elevation of the road at the cut is
Figure 9. Skyline, location 10, schematic section
about 1450 feet. The cut is normal to the axis of a small secondary interfluve trending southeast. The site is within an area of loess (22) deposited on a soil mantle underlain by Miocene Columbia River basalt (28). On the soil map the area is shown as Cascade loam (20).

The loess mantle (X) varies in thickness in the section from a maximum of nearly 7 feet at point 1, to less than 12 inches at point 2. At point 1 the A horizon is brown, silt loam, very friable, with very abundant iron/manganese cemented shot from 1 to 12 mm. in diameter with most near 5 mm. and abundant plant roots. The B2 horizon is yellowish brown, silty clay loam, with weak, coarse prisms breaking to moderate, fine, angular blocks. Moderately developed, brown cutans are common on ped surfaces. With depth, structure becomes coarser and by 48 inches only thin, brown, clay cutans are found on vertical faces of coarse prisms of light yellowish brown, very finely porous, silt loam. Fine flakes of muscovite mica sparkle throughout the loess.

Beneath the loess is yellowish red silty clay (Y) with strong, medium, angular prisms and fine angular blocks coated with continuous, red cutans and discontinuous, black, iron/manganese coatings. Interpedal cracks are apparent on drying of the material and there are only few, fine, tubular pores. There is no visible mica. The character of the material changes little with depth:
structure weakens to moderate, clay cutans are thicker on coarser peds, iron/manganese coatings are fewer and smaller, there are common, fine, rounded, polished shot, common, fine, tubular pores and interpedal cracks, and no visible mica.

The two dissimilar materials are somewhat intermixed in a zone about 12 inches thick at their boundary. The boundary does not conform to the present surface. Even if it had not already been shown that the silt was of loessial origin (22), some such explanation would be suggested by a case such as this. Whether or not it is loess, the upper material is clearly not related to its clay substrate morphologically or mineralogically, and it could not have reached its present topographic position other than through wind action in the first instance.

On the basis of its morphology, and the fact that it is integrated by a diffuse lower boundary with weathered bedrock, the red clay represents the Y soil system. Correlation of the soil developed in loess is not so direct. In previous cases the X soil has been developed in colluvium of local origin. There appears to be no evidence for an episode of colluviation antecedent to loess deposition unless the mixing across the boundary between these two dissimilar materials, silt and clay, can be interpreted in this way. This is true in nearly every case of superposition of these materials seen in the investigation,
and many such examples are to be seen in the zone of loess deposition.

The morphology of the soil in loess is compatible with the hypothesis that it is at least penecontemporaneous with the X soil system, and in later discussion it will be so regarded. Its degree of development is much less than that associated with the Y soil system, but much greater than that of the W soil system.

11. Gladstone. Jennings Avenue runs along the section line between sec. 8 and 17, T. 2 S; R. 2 E; Oregon City quadrangle, for nearly one-quarter mile west of Webster Road before cutting diagonally across the NE ¼ of sec. 17 to Oatfield Road. The road ascends the steep northeast slope of a ridge extending from Gladstone to Milwaukie Heights. The ridge is dominantly of Clackamas River gravels which abut against a knob of Boring lava at the Gladstone end (25). On its northeast side the ridge appears to have been scarped by the Clackamas River when it joined the Willamette River at Milwaukie rather than at Gladstone as it does now. On the soil map the area is shown as Willamette loam (11).

Beginning about 250 yards west from Webster Road at an elevation of about 150 feet, a cut on the south side of the road extends to the crest of a secondary divide at about 225 feet. The sequence of materials exposed in the
cut over a span of about 100 yards is shown schematically in Figure 10. At point 1 the A horizon of the present day soil (X) is brown, loam, very friable and porous, with some shot, and a clear, smooth, lower boundary at about 12 inches depth. The B2 horizon is brown, fine sandy clay loam, with coarse and medium prisms coated with thin, discontinuous cutans which increase and then decrease in frequency within the horizon to a gradual, smooth, lower boundary, to a C horizon of brown, sandy loam. The profile contains a little rounded gravel throughout. At about 42 inches there is an abrupt lower boundary to a D horizon of mottled, brown and gray, clay and weathered gravel (Y). The clay has strong, fine, angular blocky structure, with thick, continuous cutans. Downslope the latter horizon plunges from sight and the depth of the material above it increases, and then itself dives beneath the exposed section, reappearing downslope in the lower part of the section. Its place is taken by undifferentiated, grayish brown, stone free, fine sandy loam (W), apedal, or with very weak, fine, subangular blocks, very porous, with many large cylindrical pores lined with an organic coating.

This observation of a sequence of horizons which include A, B, and C, above a further horizon of clay accumulation, designated D, indicates a reversal of an established trend in soil development that would be difficult to explain
Figure 10. Gladstone, location 11, schematic section
in terms of normal processes of horizon development. In this case the two materials are believed to be of different origin. The D horizon represents the truncated remnant of a former soil which developed within a deposit of riverine gravel. The material presently overlying it was laid down unconformably by colluvial or alluvial processes only after it had reached an advanced state of weathering, and soil development.

The undifferentiated fine sandy loam (W) is a side valley fill within the material above the D horizon (X). Its presence records an erosion cycle following a period of groundsurface stability. During the stable period a soil developed such as at point 1. This is believed to be the case because no significant horizon differentiation is observed in the side valley fill.

Three materials of different origin have been identified at this site, apart from a small, surficial post-cultural deposit. The degree of soil development which took place in these materials following their deposition and stabilization increases greatly from younger to older. Soil development in the two older materials had virtually reached the stage now observed prior to a succeeding phase of erosion. This development parallels closely the previously observed sequence of W, X, and Y soil systems. It is unlikely that two such sequences with morphologically similar analogues would be present in a relatively small
area such as the Willamette Valley, unless they had developed contemporaneously. The causal factor or factors leading to stability or instability of groundsurfaces are probably such that their operation from one point to another within quite large areas is penecontemporaneous.

12. **Fenton.** In SW ¼, NW ¼, sec. 31, T. 3 S; R. 2 E; there is a cut across the nose of a west trending spur. The site is just inside the boundary of Pleistocene Willamette terrace silts with a large body of late Pliocene or early Pleistocene Boring lava immediately east of it (25). On the soil map (11) the site is within an area of Amity silt loam which is mapped upslope to about 300 feet elevation. Beyond this, Cascade silt loam is mapped in a band between the 300 and 400 foot contours. Olympic stony loam is mapped on a steeper slope from 400 to 500 feet elevation. Aiken clay loam occupies an upland of gentle relief above 500 feet. The Amity and Cascade soils are co-extensive with silt on the slope below the 400 foot contour. Olympic stony loam is developed on colluvium.

Up to 12 feet of silt is exposed in the section. To the north and west the north and south forks of Parrot Creek are deeply incised. The Amity soil appears to have developed in relation to the present surface, so that incision of the silts must have occurred prior to development of the soil profile.
The silts rest on a surface, marked by a buried soil, whose local relief was considerably less than that of the present silt surface. The buried soil is gray, stony clay, with moderate, coarse, angular prisms and blocks with well developed pressure cutans, or slickensides. The prisms have few, fine, cylindrical pores, but wide cracks develop in the material as it dries. The boundary between the silt and the clay is abrupt. Maximum depth of the clay is 24 inches and some truncation is indicated. The lower boundary of the clay is gradual to interstratified, iron-streaked fine gravel, sand, and silt.

A small side valley truncated by the section, reveals a bed of cobbles over the gray clay, and an alluvial fill in which minimal soil development has occurred.

Auger borings were made on the slope between the cutting and the Olympic stony loam, to see if the colluvium extended beneath the silts, or vice versa. One boring was made on the north side of the road about a half mile east of the cutting and 100 yards west of a shallow scarp to a higher surface. Here the depth of silt was a little over eight feet, with a Woodburn soil in the upper six feet, above an abrupt boundary to dark grayish brown clay with fine gravel. In the upper few inches the clay possessed moderate, medium, angular blocky structure, with many thin, discontinuous, cutans and iron/manganese coatings on ped surfaces. Below a gradual boundary, the material
was brown, gritty clay, with strong, fine angular blocks, thick, continuous, dark grayish brown cutans, and many black, iron/manganese coatings and shot. At about twelve feet, or four feet within the buried soil, there was a gradual change to a horizon of brown clay, massive or parallelipipedal, very plastic, with stress cutans (7). This material continued for two feet before passing to mottled, stratified sandy loam.

Another boring was made above the scarp and about 100 yards west of a steeper slope occupied by Olympic stony loam. This revealed silt containing a Woodburn soil to a depth of four feet. Below this was a buried soil with an upper horizon of dark brown clay loam about twelve inches thick above a dark reddish brown clay with strong, fine angular blocky structure, thick, continuous cutans, and iron/manganese coatings. Little change was seen in this material other than coarsening structure through about 5 feet, after which there was a gradual change to massive gray clay with stress cutans. Boring was stopped at about 12 feet below the surface within the latter material.

Within the area of Olympic stony loam, the depth of colluvium over red clay and/or saprolite was variable from as little as 12 to as much as 48 inches. Where present, the red clay had typical Y morphology. Hard rock was seen in the roadcut near the top of the slope at an elevation of about 500 feet. Above this and within the area mapped
as Aiken clay loam, the Y soil occupied broad interfluvces of gentle relief, with more recent colluvium and alluvium carrying X soils on the steeper slopes and in side valleys.

Study of this transect yielded no evidence that would permit conclusions on the relation of the silt and the colluvium other than that they appeared to merge and that soil development within these materials was at least penecontemporaneous. Again, materials of different age have been separated stratigraphically, each containing soil development. Representatives of three soil systems appear to be present in this locality. These are: (a) the soil of minimal development in the side valley fill, (b) the soils of moderate development in the silt and colluvium, and (c) the buried soils and the soils on broad interfluvces within the upland. These are thought to represent the W, X, and Y soil systems respectively.

As with the loess, in the general case exemplified in the Skyline site, the silt appears to overlie more or less truncated Y soil directly. Although one cannot state definitely that deposition of loess, silt, and colluvium took place within the one unstable phase, one might be permitted to speculate on such a possibility. One might go on to consider the general environmental conditions that have been associated with loess deposition and instability of materials on slopes. Such phenomena in the Willamette Valley could have been associated with periglacial
or desert conditions. The latter would seem less likely because a very drastic shift of climatic zones would be necessary. On the other hand Pleistocene glaciation in the region is well recognized (1, 2) and it is not inconceivable that further work may extend the boundaries of the glaciated areas.

13. Beaver Creek. The terrain in the southeast quarter of the Molalla quadrangle is rugged. Stream incision has left only narrow strips of an upland of gentle relief separated by deep, steep-sided valleys. One such upland remnant is traversed by the Scotts Mills to Maple Grove road near Missouri Ridge. The surface of the upland rises gradually from west to east from about 900 feet to 1200 feet elevation, then curving south in the general direction of Elk Prairie, rises to more than 2,000 feet. Soils mapped in the area include Olympic clay loam and silt loam and Cascade silt loam on the uplands, Olympic stony loam on the steeper slopes to Beaver Creek, with Viola clay loam, Amity silt loam, and Wapato silty clay loam along the drainages and seeps (11).

In SE ¼, SE ¼, sec. 13, T. 6 S; R. 1 E; a north and south road leaves the Scotts Mills to Maple Grove road and traverses a narrow peninsula of Olympic clay loam. In a deep cut on the southeast side of the road a bright reddish brown silty clay with moderate, medium and fine
angular blocks coated with well developed, continuous cutans has a gradual lower boundary to highly weathered basaltic bedrock. The upper part of the red clay is more porous, with weaker structure development and thin, discontinuous cutans. This upper material in part forms the present surface and in part is separated by a stone line from a surface deposit of colluvium about 12 inches thick. The latter is grayish brown loam, with weak medium and fine subangular blocks and high porosity. The stone line marks an erosion surface cut into a pre-existing Y soil. This erosion surface was partly buried by colluvium in which the upper horizons of the soil profile are now found. Where unburied, the upper foot or so of the residual Y soil material has been modified by succeeding soil development, notably by incorporation of organic matter, degradation of cutans, and increase in porosity, especially in the first few inches.

In a rectangular area bounded by the Scotts Mills to Maple Grove road, the Beaver Lake School road, and connecting roads, there is a complex soil pattern which could be interpreted on the basis of the presence of elements of X and Y soils in different degrees. Olympic clay loam appears to be developed in a more or less truncated Y soil. Olympic silt loam and Cascade silt loam appear to have composite profiles, with Y soil material forming the B2 and lower horizons while the upper horizons have formed in X
material. Olympic stony loam is developed in X colluvium of varying depth. This is commonly deposited on bedrock surfaces on steeper slopes, but may also overlie lenses of truncated Y soil material or saprolite. In SE \( \frac{1}{4} \), SE \( \frac{1}{4} \), sec. 15, a roadcut shows reddish brown X colluvium containing few stones, separated from Y material and saprolite at about sixty inches depth by a stone line which includes mudballs. Viola clay loam is a soil with a well developed B2 horizon which is mapped in seep areas at the base of slopes. It may also be a composite soil. Amity silt loam and Wapato silty clay loam are developed in deeper, fine textured, presumably X alluvium along drainages. At the same time part of the materials thought to be X may in fact be W. No clear stratigraphic evidence was noted to warrant their separation as such.

14. Fern Ridge. A series of cuts along a road traversing sections 6, 5, 4, 3, 2, and 1, T. 9 S; R. 1 E; Lyons quadrangle, demonstrates sequences of materials and soils which appear to correlate well with those described previously. Sites located in NW \( \frac{1}{4} \), SW \( \frac{1}{4} \), SW \( \frac{1}{4} \), SE \( \frac{1}{4} \); and SE \( \frac{1}{4} \), SE \( \frac{1}{4} \); sec. 3, T. 9 S; R. 1 E; are described below. The first of these is located within an area mapped as Stayton lavas (21), the other two are within an area shown as Mehama volcanics (21). The road traverses the lower slope and pediment slope to higher country to the north.
and the cuttings are made through the terminal portions of spurs extending into a broad, moderately dissected, high valley. The locality is known as Fern Ridge. Polk clay loam is mapped on the upland and low interfluves and Olympic clay loam on the lower surfaces (23).

The first cut has been made in the crest and east slope of a spur at an elevation of about 1,020 feet. The axis of the spur slopes steeply south. The cut shows reddish brown clay (Munsell, 2.5 YR) with strong, fine, angular blocks, and thick, continuous cutans, with a gradual lower boundary to saprolite. The clay is separated from overlying reddish brown clay loam (Munsell, 5 YR) by a stone line of hard basalt cobbles. The clay loam is relatively stone free. It is friable, with moderate, subangular blocky structure, while cutans are absent or thin and discontinuous. This in its turn is overlain by discontinuous, cobbly or stone free, dark grayish brown loam, which is apedal or weakly aggregated in crumbs and very friable and porous. This sequence of materials was interpreted as including soils of three different systems, Y, X, and W, the older separated from the younger by unconformities. The Y soil was truncated during the erosion cycle which left the lag gravel, indicated by the stone line, and X colluvium above it. In this case truncation is thought to have removed all of the Y soil above the B3 horizon. The X soil was later subjected to less extensive
removal and shallower burial during a W erosion cycle in which the W colluvium was deposited.

The second site is a cutting through a spur of lower relief at an elevation of 950 feet. There is a steep back-slope to the primary divide to the north. This site is about one-half mile east-southeast of that described above. Here a stone line separates saprolite below from overlying brown, almost stone free colluvium. Soil development has taken place in the colluvium. The morphology of the soil at this site correlates it with the soil at the previous site identified as X. Again there are no apparent criteria for the separation of W. It is therefore concluded that a pre-existing Y soil was removed at least to within the C horizon before burial by the colluvium in which the X soil has since developed. It is also believed that the X soil was virtually undisturbed during the W unstable phase. Situations in which an X soil material rests on saprolite or hard bedrock are very common throughout the valley slope areas. In themselves they do not contain the elements of a complete proof of their origin. Nevertheless, it is thought that an abrupt boundary between soil material and hard bedrock or saprolite, even in the absence of a lag gravel, is evidence of the colluvial origin of the soil material.

The third site is on a gently sloping pediment at an elevation of 1,000 feet, one-third mile east of the
second site. An undulating surface cut in a Y soil is buried by X colluvium, which is a fine gravel in the lower part. The latter contrasts sharply across an abrupt boundary with a mottled light gray, yellowish brown and brown, plastic clay which represents Y soil at this place. The X colluvium is four to five feet thick. The B horizon of the X soil is brown clay loam, with moderate, medium and fine angular prisms, and thin, discontinuous cutans. The A horizon consists of about 18 inches of dark grayish brown loam, which could easily be a W deposit.

The soils mapped in this general area include Aiken clay loam, Polk clay loam, Olympic clay loam, Olympic silty clay loam, Olympic loam, and Olympic loam, shallow phase (23). The observations made at the three sites described above may be applied in interpretation of the genesis of these soils. In this locality the Aiken soil appears to be unburied and relatively untruncated Y soil. The upper horizons of the Polk soil are developed in finer textured X colluvium overlying a truncated Y soil which provides the B2 and lower horizons. Olympic clay loam is similar but in this case truncation of the Y soil appears to have been greater, so that the depth to bedrock is commonly less than six feet. A stony phase of Olympic clay loam has been mapped elsewhere, but in the area now under discussion stony patches within areas of the Polk and Olympic soils have been denoted by map inscription only. These
reflect the occurrence of coarser X colluvium as a result of more severe erosion. Both Polk and Olympic soils may contain superficial lenses of W colluvium locally forming the A horizon. The same analysis can be applied in the case of Olympic silty clay loam, Olympic loam, and Olympic loam, shallow phase. The latter soil is more probably developed in shallow W colluvium. Unweathered basaltic bedrock or boulders occur within seven to twenty-four inches below the surface of Olympic loam, shallow phase (23).

15. Shaw. In the vicinity of Shaw the relocation of state highway 222 passes diagonally across the SW ¼, sec. 10, NE ¼, sec. 15, and the SW ¼, sec. 14, Stayton quadrangle. A series of roadcuts yields much information bearing on the genesis of soils in this area. The cuts to be described lie within a large area mapped as Stayton lavas (21). The soil map (23) shows Olympic clay loam as the dominant soil of the area. Waldo clay loam occupies small areas of poor drainage along ephemeral streams. Polk clay loam and Aiken clay loam cover larger but still relatively small areas of the upland. The local topography is undulating. The area is separated from the Salem Hills proper by the valley of Mill Creek, and from the Waldo Hills by an extensive upland of gentle relief, from 400 to 500 feet in elevation, between Shaw and Macleay.
In the first cut in SE ½, SW ½, sec. 10, T. 8 S; R. 2 W; at 550 feet elevation, a thin but relatively uniform, brown soil mantle is noted as continuous over weathered bedrock containing boulders of hard basalt on the one hand, and a lens of reddish brown clay on the other. Since it retains its uniformity over both substrates it is considered to be a colluvial deposit independent of either of them. The morphology of the soil developed in this colluvial material correlates it with the X soil system. The morphology of the clay is that associated with the Y soil system. Although the clay has a gradual lower boundary with weathered bedrock, the boundaries between the colluvium and its substrates are clear to abrupt.

About one-eighth mile southeast of the county road in SW ½, SE ½, sec. 10, T. 8 S; R. 2 W; and about one-quarter mile from the southeast limit of the first cut, a lens of reddish brown clay representing a truncated Y soil occupies a depression within weathered bedrock on the crest of a low spur trending northeast. A thin, brown mantle of X colluvium overlies both the clay on the crest and weathered bedrock on either side. Truncated Y soil also reappears after an interval, downslope. The lower boundary of the colluvium, whether to Y clay or bedrock, is clear to abrupt, while that between Y clay and weathered bedrock is gradual.

In SE ¼, SW ¼, sec. 14, T. 8 S; R. 2 W; the new road cuts through a low spur trending southwest. The site is
about 1½ miles southeast of the second site described above. On the northeast side of the road, an undulating weathered rock surface is overlain by reddish brown Y clay. There is a thin lens of weathered gravel within a shallow depression in the bedrock surface under Y clay. Although the boundary between Y clay and the materials below it is gradual, there is here the possibility that the Y clay is depositional. If this is true, a long time has elapsed since its deposition. The surface mantle is again brown X colluvium, which is thicker in the northwest half of the section. On the other side of the road the same sequence of materials was noted except that the gravel was absent and the Y soil material was thinner over weathered bedrock.

Consideration of these three sites leads one to conclude that Olympic clay loam as mapped in this locality is a composite soil with its upper horizons developed in X colluvium, while the lower horizons are those of the more or less truncated Y soil. Inspection of the sections described suggests the presence of inclusions within the mapped series in which the soil is formed in shallow X colluvium directly overlying weathered bedrock. Many examples of this have been noted. One clear example is in SE ¼, SE ½, sec. 21, T. 7 S; R. 1 W; at an elevation of 1500 feet, in the Waldo Hills about one-third mile west of Center View School. In a roadcut on the north side of
the road a stone line separates highly weathered basaltic bedrock and 12 to 18 inches of reddish brown colluvium in which an X soil has developed. There are tongues of Y clay below the stone line but otherwise the Y soil has been completely removed. Here the soil is mapped as Olympic clay loam, shallow phase, with a map notation to indicate some stoniness (23).

16. **Happy Home.** About one-half mile west of Happy Home School in NW ¹⁄₂, SE ¹⁄₂, NW ¹⁄₂, sec. 10, T. 12 S; R. 1 W; Lebanon quadrangle, the county road crosses a north trending spur mapped as Oligocene Mehama volcanics (4). There is a cut on the south side of the road as it descends the west sideslope of the spur at about 490 feet elevation. Olympic clay loam is the soil of general occurrence on uplands in this locality (13).

At point 1, the sequence of horizons includes A, B2, and B3, over bedrock (Figure 11). At point 3, only the A horizon is present over harder bedrock. At point 4, a horizon having the same morphology as the B3 horizon at point 1, occurs between the A horizon and softer bedrock. The B2 and B3 horizons are truncated west of the break in slope at point 2, and have been completely removed from that part of the slope on which the A horizon overlies bedrock. Downslope the B3 horizon reappears, increasing in thickness towards a small side valley. The record here
Figure 11. Happy Home, location 16, schematic cross-section
is of an erosion cycle eating upslope into the upland subsequent to development of the B2 and B3 horizons. The A horizon downslope of point 2, is developed in colluvium deposited during the same erosion cycle. Upslope of point 2, the surface may have remained more or less intact, though no morphological criteria were observed in the field that would justify a separation within the A horizon between points 1 and 3.

The A horizon is dark brown heavy silty clay loam, going to silty clay loam at point 2, with weak crumb structure, abundant tubular and interstitial pores, and a clear, smooth, lower boundary. The B2 horizon is brown medium clay, with medium, angular prisms and blocks breaking to fine, angular blocks, many tubular and interstitial pores, thin and discontinuous yellowish red cutans, and a gradual, smooth, lower boundary. The B3 horizon is brown sandy medium clay, with coarser and weaker structure, fewer pores, and a clear, smooth, lower boundary. It is quite similar to the B2 horizon. The bedrock is soft, well weathered Mehama volcanics. The series includes nonmarine tuffs and breccias, partly fluviatile in origin (4). The rock at this locality is stratified and of fine particle size. It contains thick cutans and its state of weathering appears to represent a much longer period of weathering than the soil development would indicate.
Two soil systems are represented. These are more likely the X and W systems than the Y and X systems, though the rock weathering is thought to have occurred prior to initiation of X soil development. The area in which the Happy Home site was described seems to have undergone severe erosion almost generally in the X unstable phase. Hard bedrock occurs close to the surface in areas mapped as Stayton lavas (4). In SE 1/4, SW 1/4, sec. 15, T. 12 S; R. 1 W; there is only about twelve inches of colluvium over hard basalt which forms a gently sloping pediment. In SE 1/4, NW 1/4, sec. 15, thin colluvium and side valley alluvium is separated by a stone line of basalt cobbles from underlying soft Mehama volcanics.

17. **Brownsville.** About three miles east of Brownsville an island hill of basaltic rock stands, surrounded by alluvium, in the angle formed by Mountain Home Road and the Crawfordsville road north of the Calapooya River. In NE 1/4, NE 1/4, sec. 4, T. 14 S; R. 2 W; at about 400 feet elevation, there is a cut into a bank on the east side of Mountain Home Road. The soil map (13) shows Olympic stony loam on the upland and Wapato silty clay on the bottomland.

The sequence of horizons revealed in the cut face includes A, B2, B3, and C, over weathered bedrock. The A horizon is dark brown stony silt loam, with moderate,
fine, subangular blocks and rounded pellets, friable, with many medium tubular and interstitial pores, many subangular and subrounded basalt cobbles, occasional iron/manganese concretions, and a clear, smooth, lower boundary. Immediately below the surface few inches the material is cobbly silty clay loam, with weak, medium, angular blocks which break easily to aggregates as described above. Below an abrupt, smooth boundary at 14 inches, the B2 horizon is dark brown, redder than above, heavy clay, with strong, medium, angular prisms and fine angular blocks with moderately thick, continuous cutans, and is speckled with fine fragments of weathered rock, though hard cobbles such as are found above 14 inches are conspicuously absent. Structure becomes coarser with depth to a clear, smooth, lower boundary at 22 inches. The B3 horizon is reddish yellow gritty medium clay, with dark brown and reddish brown, thick, continuous cutans on the faces of strong, coarse and medium, angular prisms and medium, angular blocks. Below 33 inches the horizon is gritty light clay and structure is of moderate grade. There is a clear, smooth, lower boundary at 43 inches to white-speckled, olive, gritty clay loam C horizon, with thick, continuous cutans on the surfaces of moderate, coarse, angular prisms of saprolite. At 50 inches a clear, smooth boundary marks a change to coarse sandy clay loam, with moderate, coarse parallellipipedal structure, and at 56 inches a gradual,
smooth boundary separates this material and sandy clay
loam saprolite, which is harder and with weaker structure
tending to an apedal condition.

The material above the B2 horizon is colluvium de-
posited on an old soil considered to represent the Y soil
system because of its morphology and its relation to bed-
rock. The pre-existing Y soil may have been truncated.
Specks of weathered rock were noted in the present B2
horizon and this condition has been associated elsewhere
with the B3 horizon of Y soils. Soil development has
taken place in the cobbly X colluvium, and below 2 inches
a textural B horizon appears separable. This seems to
have been included in the A horizon of the Olympic stony
loam profile (13, p. 37).

18. Yarnell. Near Yarnell Church, relocation of
the road from Hayden Bridge to Mohawk in the Marcola
quadrangle has required a cut nearly normal to the axis
of a spur sloping steeply west. The location is SW ¼,
NW ¼, SE ¼, sec. 17, T. 17 S; R. 2 W. The soil map (10)
shows this area as Olympic clay loam, though the soil
exposed over the greater part of the cut face is morphologi-
cally like the Dixonville series. Bedrock at this site
is much weathered and appears to be sedimentary. Cobbles
and stones within the soil zone are basalt. The section
(Figure 12) is on the west side of the road at an elevation
Figure 12. Yarnell, location 18, schematic cross-section
of about 550 feet.

Over the greater part of the cut the soil is thought to represent the X system and to be developed in colluvium deposited on an erosion surface cut in weathered bedrock. On the north slope there is a lens of brown clay containing lime concretions. This contrasts sharply with the noncalcareous clay loam to clay over the rest of the exposure. The lower boundary of the calcareous clay is gradual to weathered bedrock, though the boundary between bedrock and the material thought to be colluvium is abrupt. The brown clay is considered to be a remnant of a pre-existing Y soil.

That the W system does not lack representation in this area is suggested by the common observation of shallow, cobbly soils of minimal profile development, with abrupt lower boundaries to hard bedrock, on steep south and west slopes. It is not uncommon to observe soils of moderate development in colluvium, with an abrupt lower boundary to bedrock, which have a stone line at about 12 inches below the surface. The latter presumably separates W and X materials. In NE ½, SE ½, sec. 18, T. 17 S; R. 2 W; a stone line separates 12 inches of gray W material from reddish brown X material overlying bedrock. In SE ¼, NW ¼, NW ¼, sec. 17, T. 17 S; R. 2 W; a cut across a small, but perfectly formed, alluvial cone shows undifferentiated grayish brown, fine gravelly loam, thought to contain a
W soil. In this area it is rare to find anything of the Y soil other than tongues of clay within weathered bedrock.

19. Eugene. In the SW ¼, NE ¼, sec. 3, T. 18 S; R. 4 W; Eugene quadrangle, the road runs northeast across a gentle northwest slope. The area is mapped as lower Oligocene Fisher formation with upper Oligocene Eugene formation and a large body of Oligocene or younger basalt upslope (27). The area is shown as Melbourne clay loam on the soil map (10).

A shallow cut on the southeast side of the road (Figure 13) shows two interfluves of sedimentary bedrock covered with a thin soil mantle. The fill between them is brown clay, with strong, medium and fine, angular blocks coated with continuous cutans, underlying material like that on the interfluves, and separated from it by a line of basalt cobbles. This stone line records an erosion cycle during which colluvium (X) was deposited on an erosion surface cut in sedimentary bedrock (Z) and a pre-existing soil of the Y system (Y).

20. Elmira. In the NE ¼, SW ¼, sec. 21, T. 17 S; R. 6 W; Elmira quadrangle, the county road runs across a saddle in a north-south ridge. A cutting on the south side of the road extends from the west slope, up over the saddle at 700 feet elevation, and down the east slope.
Figure 13. Eugene, location 19, schematic section
Bedrock in this area is argillaceous sandstone of the middle Eocene Tyee formation (27). On the soil map (10) the area is shown as Melbourne clay loam, red subsoil phase.

Two to five feet of reddish brown loam to clay loam, friable and porous, with thin, discontinuous cutans on the surfaces of moderate, medium, subangular blocks in the B2 horizon, is separated by a stone line from underlying materials. Generally the material below the stone line is weathered bedrock. Thin lenses of reddish brown to brownish red clay are found between the stone line and bedrock at several places. At still other places deep pockets and tongues of this clay are seen within the weathered bedrock.

The stone line marks an erosion surface and indicates that the overlying material was deposited as colluvium. The lenses and tongues of red clay represent a pre-existing soil of the Y system which had reached an advanced stage of development before its destruction. Melbourne clay loam, red subsoil phase, is a composite soil throughout large areas in the Elmira quadrangle. The depth of the "red subsoil" is determined by the vagaries of the erosion process.

In SE ¼, NE ¼, sec. 22, T. 17 S; R. 6 W; a ridge crest (elevation 750 feet) has been completely stripped. The A horizon is grayish brown loam, with weak, fine, subangular blocks, many medium tubular pores, and common small cobbles. This may rest directly on bedrock within 12
inches, or it may have a clear, smooth, lower boundary to a B horizon which is yellowish brown clay loam, with thin, discontinuous cutans on the surfaces of medium, angular blocks, many fine and medium tubular pores, which are often filled with organic debris, and small inclusions of dark reddish brown clay and rock fragments, both of which are coated with thick cutans. If present, the latter horizon has a clear, irregular, lower boundary to weathered bedrock at about 18 inches, in which tongues of red clay may be present.

In the NE ¼, sec. 20, T. 16 S; R. 5 W; Elmira quadrangle, Territorial Road rises to about 525 feet over a saddle in a ridge trending northeast. The crest of the hill across the saddle to the southwest is at about 650 feet, while that to the northeast rises a little higher. The soil map (10) shows Sites clay loam on the ridge crest northeast of the road with Melbourne clay loam, reddish subsoil phase, on the sideslopes, saddle, and also the ridge crest to the southwest, while Melbourne clay loam forms a pear shaped area at the head of drainage to the south. Though such a clear demonstration of the stratigraphic relations of the X and Y soil systems is not common, other similar examples occur in the E ½, sec. 16, T. 15 S; R. 5 W; the SW ¼, sec. 30, T. 15 S; R. 5 W; and in the NE ¼, sec. 18, T. 18 S; R. 5 W. On the other hand, large areas of Melbourne clay loam, red subsoil phase,
occur on the uplands in the western half of the Elmira quadrangle, as well as generally on uplands underlain by sedimentary bedrock on the western side of the valley. Melbourne clay loam, red subsoil phase, is the analogue in such areas of the soil so commonly seen in the Salem Hills over basalt, which was described at the Jackson Hill site (location 1).

21. **Muddy Creek.** In NE ¼, SE ¼, sec. 29, T. 15 S; R. 3 W; Eugene quadrangle, the county road crosses the north fork of Muddy Creek at 340 feet elevation. Muddy Creek is a seasonal drainage conducting excess waters during the rainy season over an extremely tortuous route to join the east channel of the Willamette River near Stahlbusch Island. The area is shown as Quaternary alluvium on the geological map (27). A section revealed in a deep roadside drain is shown schematically in Figure 14. The section crosses a boundary, marked by the sand filled channel (W) between Willamette silt loam (X) and Clackamas gravelly loam (X) on the right of the figure (13).

As mapped in this locality, Willamette silt loam is a soil of moderate development in brown silts of alluvial or lacustrine origin. In the B2 horizon thin, brown cutans are continuous on the surfaces of moderate, coarse and medium, angular prisms. Where the silt is deep enough a C horizon is reached within five or six feet. At the
Figure 14. Muddy Creek, location 21, schematic section
present site the depth of silt is barely sufficient for this above a grayish brown heavy clay, which contains angular gravel and fine grit. The clay has weak, coarse, angular blocky structure, with thick, continuous cutans. In this area the clay is often found closer to the surface, where it forms the B2 horizon of Dayton silty clay loam, dark colored phase. In other areas Dayton soils have been mapped in deep silts and the clay described above is either absent or deeply buried.

Across the narrow channel filled with sand (W) there is a bed of apparently unweathered gravel covered by 6 to 12 inches of silt. This sequence represents the Clackamas gravelly loam soil as mapped in this area. The surface here is somewhat lower than that of Willamette silt loam. The gravel is the channel deposit of a much larger stream that once flowed here. The narrow sand filled channel represents a later and weaker phase of stream cutting and filling. Soil development in the gravel and in the sand is considerably less than in the silt, though in this the different character of the materials must be kept in mind.

The clay (Y) is regarded as a paleosol that achieved a considerable degree of development before burial by the silts in which subsequent soil development has given the Willamette silt loam profile. Cutting and filling represented by the silt and gravel at the lower level, was either later than or penecontemporaneous with deposition
of the silts. Thus at least two and possibly three episodes of soil formation are represented. The paleosol and Willamette silt loam are regarded as representing the Y and X systems respectively. The Clackamas soil may represent either the X or the W system.

Other occurrences of the Y paleosol beneath Willamette silts (3, p. 12) have been noted in various places. Amongst these is the very fine exposure in the undercut east bank of the Willamette River at Irish Bend in sec. 7, T. 14 S; R. 4 W; Halsey quadrangle, where about eight feet of silt can be seen resting on clay over gravel for nearly one mile. The paleosol at Irish Bend was referred to by Allison (2) as the commonly occurring buried soil zone between Willamette silts and gravels of the Linn stage (3, p. 11). Excavations, particularly the one for extension of the Memorial Union building in 1960, and others on this same level on the campus of Oregon State University, have revealed a gritty clay almost identical morphologically with that described above. A similar clay, with an upper boundary suggestive of gilgai microrelief, may be seen at shallower depths from 3 to 6 feet in a cutting on the west side of U. S. 99W near Lewisberg. Another such clay is exposed in a cutting on the east side of the road on the southwest slope to Knox Butte. Other occurrences have been noted in the Aumsville - Marion area in the Stayton quadrangle. It is tempting to consider a further
correlation with the Y clay of the Fenton site (location 12) which is astonishingly similar morphologically. The difficulty here is that although the clay is commonly found in the valley south of Albany, it is apparently of rare occurrence north of Salem.

22. Knox Butte. On the east side of the road as it ascends the west slope of Knox Butte there is a cutting revealing Quaternary Willamette silts and white tuffaceous sediments of the Oligocene Eugene formation (3). The cut is in the SW ¼, sec. 35, T. 10 S; R. 3 W; just north of the boundary to T. 11 S; at an elevation of about 250 feet. On the soil map (13) Courtney clay loam fringes Olympic silt loam higher on the slope.

Between the silts and the tuff there is a layer of dark gray clay with moderate, coarse and medium angular, and medium and fine subangular, blocks coated with cutans. At the base of the clay there is a stone line of cobbles of basic igneous rock marking an erosion surface and indicating that the clay is of colluvial origin. The upper slopes and crest of Knox Butte are composed of basic intrusives of probable Miocene age (3). These rocks probably supplied the cobbles forming the stone line. The silts were laid down over the colluvium following the formation of a soil in the latter material. A soil also developed in the silts either before, or more probably following,
a phase of stream incision during which the silts, clay, and tuff were truncated to form the present slope. Cobbles similar to those of the stone line were found over tuff on this slope.

Within one-quarter mile along the road north of the cut described there is another at about 275 feet elevation truncating a small side valley in tuffaceous sandstone. The side valley has been filled with light grayish brown silt in which the present soil has developed. In the bottom of the side valley, between the silt and bedrock, there is a thin lens of brown clay with strong, fine, angular blocks coated with cutans. The lower boundary of the silt is abrupt to bedrock or clay. The lower boundary of the clay is gradual.

North of Knox Butte, the road first crosses silt-mantled Eugene formation and then Lacomb gravel (3). The gravel forms a somewhat dissected terrace, mantled with silt, rising from 300 to nearly 400 feet elevation against the southeast slope of Hardscrabble Hill. In NE ¼, NW ¼, sec. 26, T. 10 S; R. 3 W; at 330 feet elevation, grayish brown silt is about 18 inches thick over a stone line of hard gravel. Below the stone line there is stone free brown and gray mottled clay with strong, medium and fine, angular blocks coated with thick continuous cutans and discontinuous iron/manganese coatings. About two feet below its upper surface the clay passes gradually to clay
with highly weathered, soft gravel in place. The gravel can be easily cut with a spade. Only a few hard stones occur in this material, but their number increases with depth.

The silts were deposited on an erosion surface cut into an old soil developed in the gravel. The present soil is composite, with the A and B1 horizons developed in the silt, while the B2 and lower horizons are those of the truncated paleosol. Soil development within the silts is moderate and is associated with the X system. The degree of development of the paleosols developed in terrace gravel and colluvium is very much greater and they are regarded as representative of the Y soil system.

23. Bear Branch. About one mile south of the North Santiam River, on the section line between sec. 28 and 29, T. 9 S; R. 1 W; the road ascends a scarp cut in Pleistocene terrace gravel (21). On the soil map (13) the area is shown as Salkum clay loam. A cutting on the west side of the road at about 425 feet elevation shows truncation of the gravel at the scarp.

Above the slope break, the sequence of soil horizons includes A, B2, B3, and C. The B2 and lower horizons are truncated on the scarp by an erosion surface marked by a stone line. On the scarp the A horizon is clearly colluvial. Above the scarp the surface rises in a gentle slope to the
south. The morphology of the A horizon is uniform both above and below the break in slope at the top of the scarp. The terrace surface above the scarp has been dissected and the slopes have been colluviated. Dissection is more severe on south and west slopes, where up to two feet of reddish brown, generally cobbly colluvium may be seen over weathered gravel. There are areas, such as SE ½, sec. 29, T. 9 S; R. 1 W; where the old soil still seems to be virtually intact. The thickness of the A horizon in these areas is near or below the lower limit described for Salkum clay loam (13, p. 61). At such places it is light grayish brown in color rather than brown or reddish brown.

The morphology of the brown or reddish brown B2 horizon developed in the gravel is very similar to that of the same horizon of Y paleosols within the study area regardless of the material in which it has formed, whether this be derived from basic igneous or sedimentary rock, or Pleistocene gravel deposits older than those of the Linn stage (3, p. 11). On the other hand the degree of development of the A horizon is moderate and in many places it can be shown to have developed in younger colluvium. Thus Salkum clay loam is thought to be a composite soil, with components of both X and Y soil systems in varying thickness. In places it appears to be a Y soil almost wholly.
24. **Bellevue.** In the NW ¼, sec. 27, T. 5 S; R. 5 W; Sheridan quadrangle, the Amity to Bellevue road traverses a small spur between two side valleys draining to Deer Creek. The cut on the south side of the road shows about twelve feet of silt overlying weathered gravel, of which up to six feet is exposed. The top of the cut is at about 180 feet elevation. The soil developed in the silt is mapped as Willamette silt loam (12). This is a soil of moderate development, with clearly differentiated A, B2, B3, and C horizons. It is correlated as representing the X soil system. The gravel below the silt is well weathered and similar in appearance to the Leffler and Lacomb gravel on the east side of the valley (3, p. 9). Soil development within the gravel had reached an advanced stage prior to burial and the paleosol is correlated with the Y system.

25. **Dayton.** Allison (1, p. 624) described a 25 foot section in SE ¼, sec. 3, T. 4 S; R. 3 W; at an elevation near 200 feet, exposed in a roadcut on U. S. 99W northeast of Dayton. The section clearly shows eight to twelve feet of waterlaid silt overlying dark reddish brown clay with a gradual lower boundary to highly weathered basalt. A soil of moderate development mapped as Willamette silt loam (12) is seen in the upper six feet of the silt. This soil is correlated with the X system. The soil on the basaltic material had reached an advanced stage
of development prior to its burial. Because of its morphology and its relationship with bedrock, it is correlated with the Y soil system. There is some mixing across the interface between the silt and the clay. Fine laminae, reflecting conditions of sedimentation, are still present higher in the silt below the present soil. Other less perfect examples of Willamette silt overlying a Y paleosol have been noted in SE 1/4, sec. 13, T. 5 S; R. 4 W; NW 1/4, sec. 35, T. 3 S; R. 3 W; and NE 1/4, sec. 25, T. 2 S; R. 2 W.

General Considerations

Soil Groupings

Regardless of the interpretations made in the preceding sections, the soils or part soils described seem to fall into three natural groupings simply on the basis of their morphological characteristics.

W Soils. The soils of this grouping are commonly dark colored, with minimal profile development and no horizon differentiation other than that which may be apparent due to a greater amount of organic matter in the surface few inches. They may be apedal or aggregated in casts of various shapes and sizes, with abundant coarse, medium, and fine tubular pores. They are typically very well drained, though poorly drained representatives may be found in fine textured sediments along drainage ways.
soils are typically found in colluvium on the upper parts of steeper slopes, youthful side valley alluvium, and contemporary floodplain deposits along the main rivers. They are classified as Inceptisols in the Seventh Approximation (25, p. 102).

There are circumstances in which W soils are difficult to distinguish because they appear as A horizons of composite profiles. Where other evidence for their separation is not available, the only field criterion may be the presence of an abrupt lower boundary to the substrate. Such a boundary is characteristic, since the soils are too young to have become integrated with their substrate. Where W soils have developed in deeper materials, such as alluvium on the present day floodplains of the main rivers, the depth of the solum is usually no more than about 24 inches.

X Soils. The soils of this grouping occupy the largest proportion of surfaces presently exposed. They are soils of moderate development. They have well defined horizons with clear to gradual boundaries, or other features which remove them from consideration as Inceptisols. Usually they have a well differentiated B2 horizon. Structure in this horizon is medium grade, angular prismatic and subangular blocky, with thin to moderately thick, discontinuous, cutans on ped surfaces. They are porous in well drained situations, with abundant medium and fine
tubular pores, but very dense and of low porosity when
developed in fine textured materials in areas of impeded
drainage. In cases where the materials in which they are
developed are shallow over older soil material, B horizon
development has taken place within the substrate, though
the latter may be little changed as a result of this.

X soils are typically found in colluvium, alluvium,
loess, truncated old soils of the Y grouping, and sapro-
lite produced by a previous long period of weathering.
An abrupt lower boundary is typical of X soils developed
in shallow colluvium. Where the latter overlies fresh
bedrock, no visible weathering of bedrock is apparent.
When X soils have developed in alluvium, loess, or colluvium
deep enough to permit their full expression, the thickness
of the solum may be as much as 60 inches.

Soils of the X grouping are classified as Vertisols,
Alfisols, Mollisols, and Ultisols in the Seventh Approxi-
mation (26, p. 102-104).

Y Soils. A complete profile representing this group-
ing has not been identified without qualification. The
nearest approach to this condition may be seen in upland
areas of gentle relief and on part of the surface of dis-
sected, old gravel fans and terraces. The amount of trunca-
tion in such areas appears to be slight, but disturbance
of the surface materials seems to have been fairly general,
so that the morphology of the surface horizons is more suggestive of the X grouping. In such cases the presumed X soil is redder than typical, and this is thought to indicate little change from the Y surface horizons.

The B2 horizon of soils of the Y grouping is their most typical and most generally observed feature. The color of this horizon may range from gray to red. Field texture is usually clay of varying degree of plasticity from well drained to poorly drained situations. Structure grade is strong, with medium, angular prisms and medium and fine angular blocks, coated with thick, continuous cutans, in which reside the brighter colors. Black iron/manganese coatings are common. Porosity is low, with few, fine, tubular pores, though interpedal cracks appear on drying. Though it usually has an abrupt upper boundary to X soil, the lower boundary is gradual to a B3 horizon little different in character from the B2 apart from its coarser structure. The B3 horizon usually has a gradual lower boundary to highly weathered bedrock, inclusions of which may be found higher within the horizon. Soils of this grouping are classified as Alfisols and Ultisols in the Seventh Approximation (25, p. 103-104).

Soil development has proceeded to much greater depths than in the case of X soils. Depths of 20 to 30 feet of B2 and B3 horizon have been observed in Y soils
developed in basaltic colluvium, as at the Turner exit from U. S. 99, south of Salem.

**Soil Systems**

A number of sites have been described at which it has been possible to separate two or three superposed soils, or part soils. The primary basis for their separation is stratigraphic. When this separation is made the soils appear to fall within three morphological groupings and these have been described. The question still remains whether the morphological groupings also constitute distinct soil systems in time.

There is remarkable uniformity in the main characteristics of soils within each morphological grouping occupying broadly comparable topographic positions. All of the Y soils have gradual lower boundaries with whatever substrate they may be associated. Whether or not these substrates truly represent the parent materials of the Y soils, this integration of soil with substrate would require a long period of time. The degree of development of Y soils is also thought to reflect a long period of soil formation. Accordingly the Y soils are thought to have developed during a long stable phase.

The upper boundary of the Y soil, in every case where superposition of younger materials can be proved, is clear to abrupt. The material deposited on the more
or less truncated Y soil in the unstable phase has undergone moderate soil development. Where this material is deep enough it contains a B2 horizon. Where shallow, the upper part of the Y soil material has been described as the B2 horizon of a unit soil in soil surveys. In no case has fresh bedrock been noted to have weathered visibly with reference to an X soil. The X soils are therefore thought to have required a much shorter period of time for their formation than the Y soils. The same line of reasoning applies in the case of W soils. The period of time from the beginning of the W stable phase to the present is thought to be comparatively brief.

Within the Willamette Valley there appears to be a sequence of very long, moderately long, and brief periods of soil formation and minimal erosion/deposition interspersed with other periods of erosion/deposition and minimal soil formation, recorded at many different places quite closely spaced within a relatively small area no more than 5,000 square miles in extent. It is thought unlikely that the sequence noted at one point in this area would be out of phase with that noted at another. The fact that the same kind of sequence is found at so many points is regarded as convincing evidence of the generality of the sequence throughout the study area.

It is therefore concluded that the three morphological groupings represent three soil systems which developed in
successive K cycles with reference to groundsurfaces created in each preceding unstable phase.

Each of these groundsurfaces has geographic expression in part of the study area. The Y groundsurface, which occupies only a small part of the study area, is found in areas of stable upland of gentle relief and dissected high gravel fans and terraces above erosional slopes occupied by materials of the X or W groundsurfaces. The latter often overlie part of a former Y soil. The X groundsurface is by far the most extensive. It is composed of colluvium, alluvium, typified by the Willamette Silts formation (3, p. 12) loess, such as described by Theisen (22) and truncated Y soil and saprolite. The W groundsurface is considerably more limited in extent. It includes small deposits of colluvium on the upper parts of steeper slopes, youthful side valley alluvium, and larger areas of contemporary floodplain alluvium along the main rivers.

Implications of Soil Systems

The occurrence of paleosols in regions subjected to periodic sedimentation by various agencies, such as in glaciated regions with successive mantles of till and/or loess, or in relation to fluctuating stream cycles, is well recognized (8, p. 5; 17, 19). Paleosols have been used as stratigraphic markers in the glacial section. Glacial chronology has been influenced by estimates of the time
represented in their degree of development and the depth of the weathered zone.

In other areas the generally held view of soil formation has been that formalized by Nikiforoff (15). Soil formation is continuous. According to circumstances, slow erosion removes material from some soil surfaces and deposits it on others. Soil formation is able to keep pace with these regular, small losses or gains of material, so that the soil profile remains in a "steady state of maturity." A new soil fairly rapidly reaches this steady state with the processes operating within its environment. Once this condition has been reached there are no criteria in the materials themselves for the passage of time.

Instead of such a steady state in the relation of soil and environment, there is ample evidence in the Willamette Valley of progression in soil development through time. To be sure, a steady state may be possible over a very long period, but the evidence at hand indicates that the stable periods have not been of sufficient duration.

In contrast to the hypothesis of Nikiforoff (15), Butler (8) has proposed a periodicity in erosion/deposition and soil development. Within each period of soil development there is no steady state, but rather a progressive development away from the original state. This is verified in the Willamette Valley by the failure of W and X soils even to approach the degree of development of Y soils.
It has been suggested (8) that for the processes of
soil formation to be effective, a period of groundsurface
stability is needed, at least to the extent that any gains
or losses of material at a particular place on a ground-
surface are so slight that progressive soil development
can occur. Since soil development is a very slow process,
this implies virtually complete groundsurface stability.
On the other hand it has been shown that stable conditions
did not hold continued sway in the Willamette Valley, but
were interrupted on two occasions. The onset of erosion/
deposition resulted in partial termination of the existing
soil system and the beginning of a new one with reference
to the new groundsurface. The presence in the Willamette
Valley of three soil systems, separated by surfaces of
erosion or deposition, or both, is in complete accordance
with Butler's concept of the soil cycle (8, p. 6).

Periodicity of erosion/deposition and soil formation
must be responsive to broadly felt changes in the environ-
ment. The effects of the changes are felt so generally
that some overall factor, such as oscillation in climatic
conditions, must be responsible. Migration of broad cli-
matic zones is a distinctive feature of the Quaternary
era. Thus it seems probable that the unstable phases may
be correlated in time with climatic changes malignant to
groundsurface stability. Whatever the nature of these
changes affecting groundsurfaces in the Willamette Valley,
the W unstable phase was probably associated with a much less drastic or prolonged change than the X unstable phase, since the latter was far more general in its effects.

Commonly on hill slopes W and X soils rest on remnants of a Y soil. Moreover, evidence has been presented that there was not sufficient time for further weathering of bedrock since destruction of the Y groundsurface. Accordingly the parent material of the W and X soils cannot have weathered from rock in place. With the exception of areas mantled by loess, the characteristics of W and X soils can be related to the kind of local rock. Therefore their parent materials must be derived from erosion of the Y groundsurface, though they have been retained on the same slopes on which they were eroded. Such a process of erosion must involve upslope migration of erosion gullies or scarps and almost immediate deposition of the disturbed materials downslope. A process of this kind has been studied and described (14, p. 30). It contrasts with the generally held idea that material, once picked up, is removed from a slope into the nearest stream and is eventually deposited as alluvium or marine sediment. Colluviation of slopes is thus possible with little loss of material from the slopes.

The hypothesis for the existence of W, X, and Y soil systems and groundsurfaces in the Willamette Valley has considerable merit as a basis for future soils studies in
western Oregon. It is not suggested that the record is necessarily complete. More detailed studies than have been possible in this investigation have the prospect of finding additional cycles and/or of subdivision of those already identified. Details are obscured with the passage of time, and over a long period there is an apparent uniformity that requires very careful analysis. Moreover, within a given phase, there may be a smaller scale periodicity, related to the major phase in much the same way as interstadials are related to the main glacial stages, which may also be recognizable by close study.

The most vital implication of the present study to the study of soils is the proposition that traditional concepts of soil genesis must be tested in a new frame of reference. They are certainly not soundly based in the old.
SUMMARY

A reconnaissance survey was conducted in the Willamette Valley, Oregon, with the objective of investigating the proposition that soil formation is not continuous, but periodic, and that periods of soil formation are interspersed with other periods of general instability of groundsurfaces, involving erosion and/or burial of pre-existing soils. A further objective was the exploration of the significance of such a phenomenon, if evidence for its reality appeared convincing.

From several hundred site descriptions, twenty-five were selected for detailed study and presentation. In each case these contained stratigraphic proof of the separateness of two or three superposed soils.

These soils were correlated on the basis of their stratigraphy and morphology within one or other of three soil systems, W, X, and Y, which developed in three separate periods in reference to distinct groundsurfaces of different age, also designated W, X, and Y, each having surface expression in part of the study area.

The youngest groundsurface, W, is of limited extent. It is composed of colluvium on the upper parts of steeper slopes, youthful side valley alluvium, and contemporary floodplain deposits along the main rivers. The next older groundsurface, X, is the most extensive by far and is
composed of colluvium, alluvium, loess, truncated old soils of the Y system, and saprolite weathered in Y time or earlier. Much older than W and X, the Y groundsurface is preserved only on limited areas of stable upland or high gravel deposits of gentle relief. On the uplands it appears to be composed of materials weathered from bedrock in place, though in several instances colluvium or alluvium has been determined. In the valleys it is made up of Pleistocene gravel deposits of glacial origin.

Soils of the W system are of minimal development, with strong expression of the activity of the soil fauna. They show no horizon differentiation on uplands and minimal horizon differentiation on floodplains. Soils of the X system are of moderate development. They have a well differentiated B2 horizon in materials deep enough to contain it with medium structure grade and thin, discontinuous cutans on ped surfaces. They are very porous in well drained situations. When X is shallow over Y, B horizon development takes place within the truncated Y soil. Thus X soils are often composite. The Y soils show much greater development than X soils. Their main features are red colors on uplands, strong structure development, thick, continuous, clay cutans on all ped surfaces, and low porosity.

The existence of these groundsurfaces and soil systems of different age is comprehended in Butler's theory of K
cycles. It is considered that this provides an appropriate framework for the study of soil genesis, and could also be of great practical use in soil mapping and correlation.


