DISTRIBUTION AND CHARACTERISTICS
OF LOESS-LIKE SOIL PARENT MATERIAL
IN NORTHWESTERN OREGON

by

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DISTRIBUTION AND CHARACTERISTICS
OF LOESS-LIKE SOIL PARENT MATERIAL
IN NORTHWESTERN OREGON

INTRODUCTION

Unconsolidated materials of possible eolian origin have been recognized in the past in parts of Columbia, Multnomah, Washington, and Clackamas Counties, Oregon. As early as 1896 Diller (12, p. 485) mentioned the occurrence of loess-like silts in the Portland hills. Darton (11, p. 11) in 1909 described the silts in the Portland hills area as loess, and stated that in places the deposit was more than 100 feet thick. In 1916 Williams and Bretz (59, p. 14) stated that the prominent hills west of Portland were covered with a heavy mantle of silt or loess, possibly deposited by wind from the lower levels of the river floodplains. Traesher (47, p. 2034) in 1940 attributed to these same deposits a thickness of 200 feet. Libbey, Lowry, and Mason (31, p. 10) in 1945 found a silt deposit reaching to a depth of 40 feet in northeast Washington County. Wilkinson, Lowry, and Baldwin (58, pp. 25-31) in 1946 mentioned a silt phase in parts of the St. Helens quadrangle; they tentatively assigned this phase to the Troutdale formation. A recent map of the Pleistocene eolian deposits of the United States, Alaska, and parts of Canada (34, Map) identified the same material as a four to eight feet thick loess deposit of Wisconsin age extending from St. Helens, Columbia County, to east of Gresham, Multnomah County. In 1952 Lowry and Baldwin (33, pp. 11-13) referred to a water-laid deposit of
upper Pliocene age in the same general area.

In the soil survey reports of Washington County (53, pp. 49-51) and Columbia County (18, pp. 48-50), none of the upland soils were considered to have developed from materials of eolian origin. However, the Powell soil series was considered to have developed from water-laid or possibly wind-blown materials in the soil survey reports of Multnomah (37, pp. 75-77) and Clackamas (29, pp. 1674-1675) Counties.

In modern soil survey work in Columbia and Washington Counties, soils developed from transported silty materials of possible eolian origin have been recognized and mapped as such. Referring to the Cascade soil in Columbia County and to the Powell soil in Multnomah County, Whittig et al. (57, pp. 227-230) concluded that these soils consist largely of loess overlying older, more weathered soils.

These observations indicate the presence of a silty, loess-like deposit on uplands which is important as a soil parent material. This report supplies information about a) the geographic distribution, b) the variations in thickness, c) the uniformity, d) the morphology e) the nature and source of this deposit. Such information is necessary for understanding the soils and for efficient and accurate soil mapping in the area. Moreover, this study may contribute to a better understanding of the late Pleistocene geologic history of the area.
DESCRIPTION OF THE AREA

The general topography, drainage, and location of the area studied are illustrated in figure 1. The boundary between uplands and the terraces and floodplains of lowland areas is nearly identical with the 300 foot contour line.

The geology of the area is illustrated in figure 2. The area has a relatively mild climate, the higher uplands being, in general, colder and wetter than the lowlands along the Columbia, Willamette and Tualatin Rivers. The latter have dry, sunny summers and mild, moist winters. At stations within the study area (54, pp. 1075-1079), the average January temperature varies from a low of 36.3 degrees F. in Doraville (Columbia County) to 39.4 degrees F. in Portland; the average July temperature varies from 62.1 degrees in Doraville to 66.7 degrees F. in Portland; the average annual precipitation varies from 48.39 inches in Columbia County to 39.43 inches in Portland.

The vegetation of Columbia County and parts of Washington County consists mainly of the Douglas-fir type (25, p.33). Western hemlock, western redcedar, and grand fir were observed in association with Douglas-fir. Most prominent among the underbrush are vine maple, oceanspray, blackberries, raspberries, huckleberries, salal, Oregongrape, and ferns. Most of Multnomah and Clackamas Counties and parts of Washington County, although once forested, are now cultivated, the most important crops being vegetable crops, berries,
filberts and walnuts.

The dominant zonal soils are Brown Latosols in the western part of the area and Reddish Brown Latosols in the central and eastern part of the area (28, p. 28).
Fig. 1. GENERALIZED TOPOGRAPHY OF THE STUDY AREA

CONTOUR LINES
ELEVATION IN FEET
COLUMBIA AND WILLAMETTE RIVER
OTHER RIVERS AND STREAMS
COUNTY BOUNDARIES
TOWNSHIP BOUNDARIES

COLUMBIA WASHINGTON
YAMHILL
HILLSBORO
APIARY
CLATSKANIE
ST HELENS
DEER ISLAND
PORTLAND
GRESHAM
MULTNOMAH
CLACKAMAS
OREGON CITY
SACPOODA
100
200
300
400
500
600
700
Fig. 2. GENERALIZED GEOLOGY OF THE STUDY AREA

- Qol, RECENT ALLUVIUM
- Qgl, GLACIAL OUTWASH

PLIO-PLEISTOCENE
- Qtv, BORING LAVA

PLIOCENE
- T6v, TROUTDALE GRAVEL

MIOCENE
- Tmv, COLUMBIA RIVER BASALT

OLIGOCENE
- T6, MIDDLE TERTIARY MARINE BEDS

EOCENE
- T6v, EOCENE MARINE SEDIMENTS
- T6, SOBLE VOLCANICS
- Tov, TILLAMOOK VOLCANICS
FIELD PROCEDURES

Reconnaissance of upland soils in Columbia, Washington, Multnomah, and Clackamas counties was made in order to a) confirm the presence of soils developed from silty, unconsolidated materials, b) establish the approximate geographic boundaries, c) determine the boundary conditions between the unconforming deposit and the underlying residual material, and d) establish the source of the material.

The reconnaissance was followed by detailed study and description of soil individuals to a) identify the geologic material from which the profiles have formed in order to determine the geographic distribution and the depth pattern of the silty deposit, and b) gain detailed information about the morphology of the soils.

Soil individuals in five transects perpendicular to the Columbia River were described. The transects were chosen in order to systematically study depth variations with distance from a possible source of the silty material in the Columbia River floodplain.

Road-cuts and in some cases other existing exposures were found almost essential at the beginning of the study for adequate identification of the geologic materials because dug pits or auger borings did not present sufficient exposure for satisfactory identification.

After the characteristics of the unconformities were determined, depth measurements by means of auger borings were possible. They were used to obtain additional information about the variations in depth
and particularly to gain knowledge about the variation in thickness with respect to slope aspect.

Samples of the middle of each horizon of all the profiles along transects and of selected other profiles were collected, air-dried, ground, and stored in sealed quart cardboard containers for possible laboratory analysis.

The names of the transects are derived from the name of a town or landmark near the transect. The first number of the profile designation also marks the respective transect and the second number identifies the position which the profile occupies in the transect, the highest number designating the location closest to the Columbia River. In the case of profiles not located in transects, the first number is replaced by the letter "A". The profiles discussed by Whittig et al. (57, pp. 226-227) are designated with a letter "W". Locations of all profiles are shown in figure 3.
Fig. 3. DESCRIPTION SITES
LABORATORY PROCEDURES

Mechanical analysis

Eight profiles were chosen for mechanical analysis in order to confirm field identifications of the soil materials and to make possible quantitative comparisons of textural data.

Three profiles of the Scappoose transect (1-3,4,5), one profile near Gresham (5-3), one near Oswego (A-4), and one on Chehalem Mountain (A-14), which in the field were identified as having developed from transported silty material, were selected for mechanical analysis. The Apiary profile (A-1), developed from material identified in the field as basalt residuum, and one profile in the vicinity of Clatskanie whose identification in the field was doubtful, were also selected.

The particle size distribution of these profiles was obtained by means of the pipette method described by Kilmer and Alexander (26, pp. 15-24). The sedimentation cylinders used for the clay and fine silt determination were kept in a constant temperature room at approximately 70 degrees F.

Inconsistencies in very fine sand and consequently also in total silt and in coarse silt contents between duplicate samples suggested that the separation of the sand fraction from the silt and clay fraction by the wet sieving technique, recommended by Kilmer and Alexander (26, p. 22), was inadequate. With the same volume of water poured through duplicate samples, varying amounts of coarse
silt were washed out. This inconsistency in duplication was eliminated by including a 300 mesh sieve in the nest of sieves used for the dry fractionation of the sands by shaking as recommended by Olmstead, Alexander, and Middleton (36, p. 13).

**X-ray Analysis**

In addition to the field observation and mechanical analysis it was believed useful to rely on mineralogical data in order to a) confirm the uniformity of the material throughout its extent, and b) verify the distinction between unconforming silt deposits and underlying residual material. The B₂ horizons, developed from the silty material, and the lowest D horizons, developed from basalt residuum, of the Scappoose 1-5, the Gresham 5-3, and Chahalem Mountain A-14 profiles were selected. These three profiles represented the major geographic locations of the deposit.

The clay and silt suspension of selected horizons used for the pipette analysis was saved in stoppered 1000 ml. Erlenmeyer flasks. The 2 to 20 μ fraction was separated from the 20 to 50 μ fraction and the clay fraction by sedimentation using Stokes law (5, p. 55). The fine silts thus separated were washed repeatedly with distilled water to remove as much of the remaining clay as possible.

The fine silt was oven-dried and mounted in an aluminum sample holder.

X-ray analysis were made on a North American PhilipsCo. diffraction spectrometer equipped with a Geiger-Mueller tube and a Brown recorder. The radiation was CuKα. The scanning speed was 1
degree 2° per min. for all samples. The 1° divergence and scatter slits combined with the 0.006 receiving slit were found to be most advantageous for optimum peak height. For the recorder, the rate meter settings of 4 x 0.6 corresponding to 120 counts per second full scale with a time constant of 8 proved most successful for optimum peak height in the analysis of the B horizons. Rate meter settings of 8 x 0.6 corresponding to 240 counts per second full scale with a time constant of 4, however, were most advantageous in the analysis of the D horizons.

Preliminary investigations revealed that removal of iron oxides from some of the D horizon fine silts with sodium hydrosulfide resulted in neither better resolution nor sharper intensities of the peaks, and was therefore discontinued.

The data were interpreted with the aid of the A.S.T.M. X-ray powder data cards (3 n.p.).
RESULTS AND DISCUSSION

Identity of the Deposit

Striking unconformities between the silt deposit and underlying material were noted early in the field study. These observations correlate closely with those made previously by soil survey workers.

Where the underlying materials (designated "D" to indicate a layer below the soil proper that is not parent material) consists of latosolic, basalt residuum, it is clearly differentiated from the overlying silty material. It is typically reddish brown (5 YR 4/4 Munsell notation) when dry, very sticky and very plastic clay, with strong fine to very fine angular blocky structure. The overlying silt, however, is very pale brown (10 YR 7/4) when dry, slightly sticky, slightly plastic silt loam or silty clay loam with moderate fine angular to subangular blocky structure.

Mechanical analysis data for six profiles (Scappoose 1-5, 1-4, 1-3; Gresham 5-3; Oswego A-4 and Chehalem Mts. A-14) of silt over basalt residuum show that the D layers, derived from basalt, are in all cases, higher in clay and lower in silt than any of the horizons of the silty material, including the transitional B horizons (tables 1-6 and figures 4a, b).

The silt content of the six D horizons was compared to the average silt content of the overlying A and B horizons. By an analysis of variance calculation the difference in the silt content between the D and the A and B horizons was significant at the 1%
level.

The Apiary A-1 profile at the margin of the silt deposit has a higher clay content and a lower silt content in all horizons than any horizon in a profile developed from silty material (table 7, figure 4c). In fact, the silt and clay content of the horizons of the Apiary A-1 profile compare favorably with the silt and clay content of any of the analyzed unconforming D horizons. The silt content of the six D horizons analyzed was therefore compared to the silt content of the Apiary A-1 horizons by means of a least significant difference calculation. The least significant difference was 4.06. The difference between the average silt content of the D horizons (42.66 %) and that from Apiary A-1 horizons (42.25 %) was well within the limits of the L.S.D. No significant difference exists, therefore, in silt content between the D horizons examined and the horizons of the Apiary A-1 profile.

The Clatskanie 3-1 profile (the field identification of which was uncertain), shows a decreasing silt content and an increasing clay content with depth (table 8 and figure 4c). This profile should probably be regarded as transitional between a residual and a silt derived soil. Silty material has very likely been mixed with residual material in the A horizons.

The X-ray patterns for the three profiles examined (Scappoose 1-5, Gresham 5-3, and Chehalem Mts. A-14) show consistent differences in mineralogy of the fine silt, between D layers and the overlying material as represented by the B2 horizons (figure 8 a, b, c).
Table 1

Particle Size Distribution of the Horizons of Chehalem Mountains, A-14, Profile

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Horizon</th>
<th>Depth Inches</th>
<th>% Sand 2.0-.05 mm.</th>
<th>% V.F. Sand 2.0-1.0 mm.</th>
<th>% Sand Minus .10-.05 mm.</th>
<th>% V.F. Sand .05-.02 mm.</th>
<th>% Silt .02-.002 mm.</th>
<th>% Clay .002 &amp; less</th>
</tr>
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<tr>
<td>31</td>
<td>A1A3</td>
<td>0-19</td>
<td>11</td>
<td>7</td>
<td>4</td>
<td>71</td>
<td>36</td>
<td>35</td>
</tr>
<tr>
<td>30</td>
<td>B1</td>
<td>19-36</td>
<td>9</td>
<td>6</td>
<td>3</td>
<td>72</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>17</td>
<td>B2</td>
<td>36-58</td>
<td>6</td>
<td>1</td>
<td>5</td>
<td>66</td>
<td>34</td>
<td>32</td>
</tr>
<tr>
<td>12</td>
<td>B31</td>
<td>58-73</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>66</td>
<td>32</td>
<td>34</td>
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<tr>
<td>25</td>
<td>B32</td>
<td>73-89</td>
<td>9</td>
<td>6</td>
<td>3</td>
<td>60</td>
<td>22</td>
<td>38</td>
</tr>
<tr>
<td>4</td>
<td>D1</td>
<td>89-106</td>
<td>7</td>
<td>5</td>
<td>2</td>
<td>44</td>
<td>15</td>
<td>29</td>
</tr>
<tr>
<td>24</td>
<td>D2</td>
<td>106-126*</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>40</td>
<td>15</td>
<td>25</td>
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Table 2

Particle Size Distribution of the Horizons of Gresham, 5-3, Profile

<table>
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<tr>
<th>Sample Number</th>
<th>Horizon</th>
<th>Depth</th>
<th>% Sand 2.0-.05 mm</th>
<th>% Sand Minus V.F. Sand</th>
<th>% V.F. Sand</th>
<th>% Silt</th>
<th>% C. Silt</th>
<th>% F. Silt</th>
<th>.002 &amp; less</th>
<th>% Clay</th>
</tr>
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<tr>
<td>18</td>
<td>A1</td>
<td>0-6</td>
<td>15</td>
<td>7</td>
<td>8</td>
<td>71</td>
<td>40</td>
<td>31</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>A3</td>
<td>6-31</td>
<td>12</td>
<td>6</td>
<td>6</td>
<td>74</td>
<td>41</td>
<td>33</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>B1</td>
<td>31-41</td>
<td>11</td>
<td>3</td>
<td>8</td>
<td>69</td>
<td>39</td>
<td>30</td>
<td>20</td>
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<tr>
<td>16</td>
<td>B2</td>
<td>41-53</td>
<td>13</td>
<td>4</td>
<td>9</td>
<td>70</td>
<td>40</td>
<td>30</td>
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<tr>
<td>7</td>
<td>B31</td>
<td>53-69</td>
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<td>6</td>
<td>6</td>
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<tr>
<td>22</td>
<td>D1</td>
<td>78-113†</td>
<td>7</td>
<td>3</td>
<td>4</td>
<td>42</td>
<td>19</td>
<td>23</td>
<td>51</td>
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Table 3

Particle Size Distribution of the Horizons of Scappoose, 1-5, Profile

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<tr>
<th>Sample Number</th>
<th>Horizon</th>
<th>Depth Inches</th>
<th>% Sand 2.0-.05 mm.</th>
<th>% Sand Minus V.F. Sand</th>
<th>% V.F. Sand</th>
<th>% Silt 2.0-1.0 mm.</th>
<th>% V.F. Sand</th>
<th>% Silt .10-.05 mm.</th>
<th>% V.F. Sand</th>
<th>% Silt .05-.02 mm.</th>
<th>% V.F. Sand</th>
<th>% Silt .02-.002 mm.</th>
<th>% V.F. Sand</th>
<th>% Clay .002 &amp; less</th>
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<tr>
<td>45-41</td>
<td>A₁</td>
<td>0-10</td>
<td>24</td>
<td>13</td>
<td>11</td>
<td>66</td>
<td>28</td>
<td>28</td>
<td>38</td>
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<td>10</td>
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<tr>
<td>62-71</td>
<td>A₂</td>
<td>10-19</td>
<td>14</td>
<td>5</td>
<td>10</td>
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<td>40</td>
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</tr>
<tr>
<td>36-48</td>
<td>B₁</td>
<td>19-31</td>
<td>16</td>
<td>2</td>
<td>14</td>
<td>64</td>
<td>20</td>
<td>20</td>
<td>24</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
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</tr>
<tr>
<td>35-66</td>
<td>B₂</td>
<td>31-41</td>
<td>13</td>
<td>2</td>
<td>11</td>
<td>70</td>
<td>42</td>
<td>42</td>
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<td>17</td>
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</tr>
<tr>
<td>76-44</td>
<td>B₃₁</td>
<td>41-57</td>
<td>8</td>
<td>2</td>
<td>6</td>
<td>70</td>
<td>43</td>
<td>43</td>
<td>27</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>60-49</td>
<td>B₃₂</td>
<td>57-74</td>
<td>9</td>
<td>4</td>
<td>5</td>
<td>65</td>
<td>36</td>
<td>36</td>
<td>29</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>39-40</td>
<td>D₁</td>
<td>74-87</td>
<td>8</td>
<td>3</td>
<td>5</td>
<td>52</td>
<td>24</td>
<td>24</td>
<td>28</td>
<td>40</td>
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<td>40</td>
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<td>40</td>
</tr>
<tr>
<td>57-72</td>
<td>D₂</td>
<td>87-98+</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>42</td>
<td>15</td>
<td>15</td>
<td>27</td>
<td>54</td>
<td>54</td>
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### Table 4

Particle Size Distribution of the Horizons of Scappoose, 1-4, Profile

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Horizon</th>
<th>Depth</th>
<th>% Sand</th>
<th>% V.F. Sand</th>
<th>% V.F. Sand</th>
<th>% Silt</th>
<th>% C. Silt</th>
<th>% F. Silt</th>
<th>% Clay</th>
</tr>
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<tbody>
<tr>
<td>33-43</td>
<td>A_{1A3}</td>
<td>0-25</td>
<td>22</td>
<td>9</td>
<td>13</td>
<td>65</td>
<td>37</td>
<td>28</td>
<td>13</td>
</tr>
<tr>
<td>74-51</td>
<td>B_{1}</td>
<td>25-39</td>
<td>13</td>
<td>4</td>
<td>9</td>
<td>69</td>
<td>40</td>
<td>29</td>
<td>18</td>
</tr>
<tr>
<td>65-54</td>
<td>B_{2}</td>
<td>39-48</td>
<td>7</td>
<td>2</td>
<td>5</td>
<td>59</td>
<td>32</td>
<td>27</td>
<td>34</td>
</tr>
<tr>
<td>67-55</td>
<td>D</td>
<td>48-76+</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>36</td>
<td>15</td>
<td>21</td>
<td>61</td>
</tr>
<tr>
<td>Sample Number</td>
<td>Horizon</td>
<td>Depth Inches</td>
<td>% Sand 2.0-0.05 mm</td>
<td>% Sand Minus V.F. Sand</td>
<td>% V.F. Sand 2.0-1.0 mm</td>
<td>% V.F. Sand .10-.05 mm</td>
<td>% Silt 0.5-.002</td>
<td>% C. Silt .05-.02 mm</td>
<td>% F. Silt .02-.002 mm, less</td>
</tr>
<tr>
<td>---------------</td>
<td>---------</td>
<td>--------------</td>
<td>---------------------</td>
<td>-----------------------</td>
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<td>-----------------------------</td>
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<tr>
<td>59-38</td>
<td>A₁</td>
<td>0-4</td>
<td>26</td>
<td>18</td>
<td>8</td>
<td>66</td>
<td>37</td>
<td>29</td>
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<td>70-73</td>
<td>A₃</td>
<td>4-22</td>
<td>12</td>
<td>5</td>
<td>7</td>
<td>75</td>
<td>40</td>
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<td>13</td>
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<td>53-42</td>
<td>B₁</td>
<td>22-41</td>
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<td>1</td>
<td>6</td>
<td>73</td>
<td>39</td>
<td>34</td>
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<tr>
<td>46-34</td>
<td>B₂</td>
<td>41-63</td>
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<td>41</td>
<td>12</td>
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Table 6
Particle Size Distribution of the Horizons of Oswego, A-4, Profile

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Horizon</th>
<th>Depth Inches</th>
<th>% Sand 2.0-.05 mm</th>
<th>% V.F. Sand 2.0-1.0 mm</th>
<th>% Sand Minus V.F. Sand 10-.05 mm</th>
<th>% Silt 0.5-.002</th>
<th>% G. Silt .05-.02 mm</th>
<th>% F. Silt .02-.002 mm</th>
<th>% Clay less .002</th>
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</thead>
<tbody>
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<td>A1</td>
<td>0-7</td>
<td>21</td>
<td>11</td>
<td>10</td>
<td>66</td>
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<td>27</td>
<td>A3</td>
<td>7-15</td>
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<td>69</td>
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<tr>
<td>8</td>
<td>B11</td>
<td>15-34</td>
<td>12</td>
<td>2</td>
<td>10</td>
<td>65</td>
<td>43</td>
<td>22</td>
<td>23</td>
</tr>
<tr>
<td>13</td>
<td>B12</td>
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<td>29</td>
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<td>55</td>
<td>27</td>
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<td>28</td>
<td>D</td>
<td>79-90+</td>
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<td>48</td>
<td>21</td>
<td>27</td>
<td>30</td>
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</tbody>
</table>
Table 7
Particle Size Distribution of the Horizons of Apiary, A-1, Profile

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Horizon</th>
<th>Depth Inches</th>
<th>% Sand 2.0-0.05 mm</th>
<th>% V.F. Sand 2.0-1.0 mm</th>
<th>% V.F. Sand 0.01-0.05 mm</th>
<th>% V.F. Sand 0.005-0.002</th>
<th>% Silt 0.002-0.02 mm</th>
<th>% Silt 0.02-0.002 mm, less</th>
<th>% C. Silt</th>
<th>% F. Silt</th>
<th>% Clay 0.002 &amp; less</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>A_1</td>
<td>0-6</td>
<td>16</td>
<td>9</td>
<td>7</td>
<td>49</td>
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<td></td>
</tr>
<tr>
<td>15</td>
<td>A_3</td>
<td>6-12</td>
<td>15</td>
<td>9</td>
<td>6</td>
<td>47</td>
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<td>25</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>B_2</td>
<td>12-18</td>
<td>18</td>
<td>10</td>
<td>8</td>
<td>37</td>
<td>15</td>
<td>22</td>
<td>22</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>C</td>
<td>18-44</td>
<td>16</td>
<td>9</td>
<td>7</td>
<td>36</td>
<td>17</td>
<td>19</td>
<td>19</td>
<td>48</td>
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</tbody>
</table>
Table 8
Particle Size Distribution of the Horizons of Clatskanie, 3-1, Profile

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Horizon</th>
<th>Depth Inches</th>
<th>% Sand 2.0-.05 mm</th>
<th>% V.F. Sand 2.0-1.0 mm</th>
<th>% V.F. Sand .10-.05 mm</th>
<th>% Silt .05-.002</th>
<th>% C. Silt .05-.02 mm</th>
<th>% F. Silt .02-.002 mm</th>
<th>% Clay &lt;.002 &amp; less</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 A1</td>
<td>0-2</td>
<td>19</td>
<td>13</td>
<td>6</td>
<td>61</td>
<td>26</td>
<td>35</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>20 A31</td>
<td>2-11</td>
<td>21</td>
<td>16</td>
<td>5</td>
<td>64</td>
<td>27</td>
<td>37</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>10 A32</td>
<td>11-23</td>
<td>18</td>
<td>13</td>
<td>5</td>
<td>63</td>
<td>26</td>
<td>37</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>2 B21</td>
<td>23-43</td>
<td>15</td>
<td>11</td>
<td>4</td>
<td>55</td>
<td>20</td>
<td>35</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>19 B22</td>
<td>43-50</td>
<td>19</td>
<td>15</td>
<td>4</td>
<td>44</td>
<td>14</td>
<td>30</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>21 C</td>
<td>50+</td>
<td>15</td>
<td>12</td>
<td>3</td>
<td>46</td>
<td>15</td>
<td>31</td>
<td>39</td>
<td></td>
</tr>
</tbody>
</table>
Patterns for D layers show prominent quartz peaks but no other peaks sufficiently well defined to permit positive identification. The presence of labradorite, pyroxene, magnetite, and amphibole is suggested by some of the poorly defined peaks in the D horizons. The quartz content of the fine silt fraction of the D horizons is attributed to the severe weathering to which the basalt residuum has been subjected and to the resistance of quartz to weathering relative to other minerals originally present in the rock. The silty material, however, shows in addition to quartz peaks clearly defined feldspar peaks, to which detailed reference will be made in the following section.

On the basis of field studies, mechanical analysis, and X-ray data, the presence of a silt deposit unconformable to underlying residual materials seems to be established without doubt. In those cases where the silty material was more than eight feet deep, and where no suitable exposure deeper than that existed, it was, of course, impossible with the equipment at hand to verify the unconformities.

Nature of the Deposit

The textures of the silty material, as observed in the field, range from a silt loam in the A horizons to a silty clay loam in the B horizons. This is true for the silty material throughout its extent. The mechanical analysis data (tables 1 - 6) revealed that the greatest percentage of the material is in the silt fraction. Excluding the transitional B3 horizons, the silt content ranges from
64 to 74 %, and the clay content from 8 to 28 %, and the sand content from 5 to 26 %. In each profile the maximum occurs in the A1 horizon and the minimum in the B horizons. Except for the A1 horizons, the greatest bulk of the total sand is in the very fine sand fraction. The reason for the rather high percentages of very coarse, coarse, medium and fine sand in the A1 horizons is to be found in the presence of considerable amounts of shot. Lotspeich and Smith (32, pp. 472-473) report the same observation for the A1 horizons of several silty wind-blown silts in eastern Washington. This shot is considered to consist of local concentrations of iron, manganese, and phosphorus that may include soil material (57, p. 230 and 55, p. 40). Libbey, Lowry, and Mason (31, p. 10) refer to shot as silt particles cemented together with iron oxide.

Cumulative percent curves (figure 4a, b) illustrate the mechanical analysis data and facilitate comparison between horizons and profiles. The curves compare favorably with published curves of loess deposits in New Jersey (46, pp. 24-26), and in the Mid-Columbia Basin (13, pp. 85-87). The mechanical analysis data compare favorably with the composition of loess in Iowa (23, p. 426; 24, p. 319), Illinois (41, pp. 153-156), and Missouri (43, p. 463).

X-ray patterns obtained from an analysis of the B2 horizons of the Scappoose 1-5, the Gresham 5-3, and the Chehalem Mountain A-14 profile can be interpreted for quartz and feldspars (figure 8a, b, c), particularly albite, labradorite, and oligoclase. Anorthite, orthoclase, microcline, hypersthene, and muscovite may also be present.
Fig. 4a. CUMULATIVE PARTICLE SIZE DISTRIBUTION CURVES

SCAPPOOSE 1-3

% OF SAMPLE FINER THAN SPECIFIED DIAMETER

SCAPPOOSE 1-4

100
80
60
40
20
100
80
60
40
20

% OF SAMPLE FINER THAN SPECIFIED DIAMETER

SCAPPOOSE 1-5

100
80
60
40
20

DIAMETER OF PARTICLES IN MILLIMETERS (log scale)
Fig. 4b. CUMULATIVE PARTICLE SIZE DISTRIBUTION CURVES

CHEHALEM MTS. A-14

OSWEGO A-4

GRESHAM 5-3

DIAMETER OF PARTICLES IN MILLIMETERS (log scale)
Fig. 4c. CUMULATIVE PARTICLE SIZE DISTRIBUTION CURVES

**APIARY A-1**

% of sample finer than specified diameter

Diameter of particles in millimeters (log scale)

**CLATSKANIE 3-1**

% of sample finer than specified diameter

Diameter of particles in millimeters (log scale)
As indicated above, the silty material differs markedly from the underlying unconforming material throughout much of the area. This discontinuity in profile characteristics cannot be explained by normal soil forming processes. It is assumed that two distinct and separate layers of soil material exist. Morphological characteristics, mechanical analysis, mineral composition, and conformity with the underlying bedrock indicate that the underlying material is from a residual soil. The upper silty deposit must have been transported into the area at a time when the residual soil was well along in its development. The silty texture, narrow range of particle size, and vertical uniformity of the upper deposit indicate an aeolian origin. Moreover, the deposit is found at elevations ranging from approximately 300 to 1,000 feet, well above known water levels since deposition of the Troutdale formation in the Pliocene.

If the silty material has been transported by wind, then the following criteria must apply (8, p. 245): a) adequate source of the material, b) adequate winds with velocities capable of transporting sorted materials (44, pp. 249-255; 49, pp. 647-653), c) favorable locations for deposition (19, pp. 381-385; 15, pp. 49-53), and, according to the findings of Smith in Illinois (41, pp. 156-163), various workers in the Midwest (23, pp. 424-426; 52, p. 394; 30, p. 604) and in the East (46, p. 25; 45, p. 538), d) thinning of the deposit with distance from the source.

An adequate source of the silt is to be found in the Columbia River floodplain (figure 1). Adequate winds can be explained as
will be shown later. Favorable places for deposition are definitely present in the uplands bordering the Columbia River (figure 1). A thinning of the material with distance from the Columbia River has been observed throughout the area as evidenced by the detailed depth readings on figure 5.

Smith (41, pp. 153-156) and Douglass (13, pp. 85-89), among others, report that not only the thickest, but also the coarsest part of the wind-blown material is closest to the source; with distance from the source the texture becomes finer. Figure 4a shows the cumulative percent curves of three horizons occurring at close to equal depth of three different profiles (1-5, 1-4, 1-3) of the Scappoose transect. With increasing distance from source the amount of material smaller than 50µ in diameter increases. The same relationship holds true when the cumulative percent curves of the Oswego profile (A-4) are compared with the curves of the Chehalem Mountain profile (A-14) (figure 4b).

Thus, all the criteria for wind deposition of the silty material are fulfilled, but the question whether or not this wind-blown material can also be called loess, remains. According to the definition advanced by Flint (14, p. 175): "Loess is a buff-colored, nonindurated sedimentary deposit consisting predominantly of particles of silt size", or according to the definition by the Soil Science Society of America Committee on Terminology (42, p. 435): "Loess -- a fine grained aeolian deposit dominantly of silt-sized particles", the deposit of the study can definitely be called loess. If, however, loess has to be calcareous, as is the case with the vast
Fig. 5. THICKNESS MEASUREMENTS (INCHES) OF THE LOESS

NEARLY LEVEL OBSERVATION SITE

SLOPING OBSERVATION SITE (ARROW POINTS DOWNSLOPE)
deposits in the Midwest, then of course this deposit, containing no carbonates, is not loess. Since on the other hand the content of carbonate minerals in loess is variable, ranging as high as 40%, depending on the geologic material from which the loess originated, it seems rather futile to make the calcareous character of some loess deposits a requirement for all others. Consequently the silty material that this study is concerned with, although non-calcareous, is definitely considered loess and from now on is referred to as such.

In addition to the thinning with distance from and perpendicular to the Columbia River, referred to earlier in this section, three other kinds of depth variations have been observed: a) thinning parallel to the river, b) variation depending on slope aspect, and c) absence of the deposit on steep slopes due to erosion. The thinning parallel to the river with distance from the deepest deposits in the vicinity of Portland is illustrated schematically (figure 6) and in detail (figure 5). This thinning suggests that the center of the source of the loess must be close to Portland in the Columbia River floodplain. At this point the floodplain is also widest (figure 1).

The depth variation depending on slope aspect is such that the slopes of a hill or mountain that face the Columbia River floodplain are covered with a deeper loess blanket than those slopes facing away from the Columbia River. Depending on the point of observation along the Columbia, the slopes with the thicker mantle
Fig. 6. VARIATIONS IN THICKNESS OF THE LOESS

THINNING PARALLEL TO THE COLUMBIA RIVER

THINNING PERPENDICULAR TO THE COLUMBIA RIVER
are north slopes, northeast slopes, or east slopes. In each case the south slopes, southwest slopes, and west slopes have a thinner loess cover. Figure 5 illustrates these observations in detail. If we assume the existence of winds blowing away from a source at the river, the north, northeast, and east slopes are windward slopes and the others are lee slopes.

This variation of loess material due to aspect is independent of the variation in depth with distance from source. Figure 5 illustrates the fact that wherever the aspect variation was observed, a windward slope had a deeper loess blanket than the preceding lee slope, but a thinner loess blanket than the preceding windward slope; the first is due to aspect variations, the second is due to thinning with distance from source.

Free (15, pp. 47-53) recognized as early as 1911 that anything which decreases the velocity of the wind will favor deposition as well as retention of wind-blown materials. On a hill free of vegetation, wind velocity may be greater on the windward slope than on the lee slope due to the compression of the air mass on windward slopes and subsequent expansion on lee slopes. Thus, deposition could conceivably be greater on lee slopes than on windward slopes. The presence of vegetation, however, will cause the wind to reduce its velocity and thus to deposit its load on windward slopes, especially if the loess-laden winds move within a short distance of the ground (41, p. 163).

The role of vegetation in the retention of wind-blown material
has been further emphasized by Huntington (22, pp. 359-360), Hobbs (19, p. 384), and Shimeck (40, pp. 86-88). There is little doubt that vegetation existed previously to and throughout the Wisconsin glacial stage in the western part of Oregon. Hansen and Mackin (17, pp. 136-138) in a study of interglacial (post-Admiralty) peat near Seattle, Washington report the existence of a lodgepole pine and western white pine forest in the Puget Lowland. These same species followed by a Douglas-fir and hemlock forest are believed by Hansen (16, pp. 539-540) to have invaded the Puget Lowland in post-Vashon times. Invasion of forest vegetation into an area vacated by the ice of the Admiralty and the Vashon glacial stages indicates that forest vegetation must have been existent in areas marginal to the ice during the glacial stages. The area of this study during the time of loess deposition was in exactly such a position, since ice did not transgress the Columbia River. The fact that the proximity of the ocean as stressed by Hansen (16, p. 540) acted even during glaciation in a moderating way on the climate of the regions in question must certainly not be overlooked in considerations of this sort.

Douglass (13, pp. 88-89), in his study of soils developed from loess in the Columbia Basin, noted that the loess is deepest on the northeast slopes. This depth variation was attributed by Douglass to a) preferential accumulation on north slopes because of differences in vegetative cover, b) erosion on windward slopes and deposition on lee slopes by southwest winds after original accumulation,
and c) preferential wind and water erosion on south slopes because of difference in vegetative cover. This explanation does not apply for this study because 1) the aspect with greatest depth of loess ranges from north to east depending on geographic position within the deposit, 2) no major differences in vegetation density between north, south, east, and west slopes exist now and presumably did not exist at the time of deposition, and 3) winds from the directions causing a redeposition of the original deposits are not likely.

However well defined and clear cut the loess blanket is in most of the area (figure 7), in some locations general uncertainty persists as to the distinction between loess and water-deposited silts.

One of these problem areas is the high plateau west of Deer Island. Wilkinson et al. (58, pp. 4-39) mapped Pleistocene terrace sands and Pliocene Troutdale formation in this area. Profile 2-4 at an elevation of approximately 350 feet consists of a characteristic loess deposit over a reddish and clay textured residual material. However, profile 2-5 and 2-6 at elevations of approximately 300 feet, studied in detail to a depth of 70 inches and 80 inches respectively, do not reveal any unconformity. The general thinning pattern parallel to the Columbia River indicates that the loess blanket at the profile sites is not thicker than nine feet at the most; yet a well log observed during the course of the study close to location 2-6 and at an elevation of approximately 325 feet, revealed silty material to a depth of 40 feet. Material of this
Fig. 7. DISTRIBUTION OF THE LOESS ON UPLANDS
depth at this location cannot be explained except by water deposition. The presence of granitic erratics (58, p. 31) at elevations below 400 feet point also to the possibility of water deposition. Similar problems presumably exist also in the Shilo basin area.*

A loess blanket to a depth of several feet may very well overly silty water-laid materials in this area, but by field observation alone it is not possible to distinguish between the two.

At the eastern edge of the loess deposit in Multnomah and Clackamas Counties at elevations below 600 feet, (lower than those points at which the material was positively identified as loess), soils morphologically similar to the loess soils proper occur on what Treasher (48, map) mapped as Pleistocene glacial outwash and Troutdale formation. In the Multnomah County Soil Survey Report (37, pp. 47-98) these soils, together with soils at higher elevation now definitely considered to have developed from loess, were mapped Powell silt loam. Whittig et al. (57, pp. 228-231) in their study of a Cascade and a Powell profile, the latter originating from an area mapped as glacial outwash by Treasher (48, map), state that the Powell soil consists largely of loess overlying older more weathered soil horizons. They further state that "The profiles of both these soils exhibit unconformities marking depositional materials laid down over older, more highly weathered soil horizons."

Field observations, however, do not show a morphological unconformity in the profile, at least not at the depth indicated by Whittig.

* Personal communication, L. Piontkowski, Soil Scientist.
Furthermore Whittig's data show the unconformity in the case of the Powell soil much less clearly than they did for the Cascade soil. Mechanical analysis, for example, reveals more sand and less silt in the Powell as compared with the Cascade. The range in percent total silt for the Powell soil is 64 to 66% and for the Cascade soil is 66 to 72% when the shotty and the transitional B₃ horizons are excluded. The range in percent total silt for the Gresham 5-3 profile of this study is 69 to 74% and for the Scappoose 1-5 profile it is 64 to 71%. In addition to the above data, which are by no means conclusive, it would be difficult to explain approximately four feet of loess in Whittig's Powell area, when adjacent uplands, located in much more favorable positions for accumulating wind-blown materials, do not show an identifiable trace of loess. Furthermore, if, as will be shown later, the loess was deposited by northeast winds, it would be difficult to explain several feet of loess in an area sheltered from these winds by uplands higher than 500 feet (Corbett Heights). On the other hand it is conceivable that water sorted fine materials, notably glacial outwash and Troutdale, can produce silty soils with the same morphological characteristics as the loess soils, provided climatic conditions are similar. Nevertheless the ideas here advanced are inconclusive and additional work needs to be done, if the problem is to be solved.

The uplands west of Corbett Heights where the Powell soil series was recognized in the old soil survey report of Multnomah County are believed not to be covered by a loess deposit. The soils
have a silty texture and are supposed to have developed from Troutdale formation and in parts also from Boring lava and on the south slopes facing the Sandy River, from glacial outwash. This assumption is strengthened by the fact that the Columbia River floodplain is very narrow (less than three miles) north of these uplands, and thus the northeast winds that account for the deep deposits around Portland could not have deposited material on these uplands.

Uniformity of the Loess Deposit

Aside from variations due to soil development and distance from source, field morphological observations, mechanical analysis, and X-ray data confirm the horizontal uniformity of the loess cover throughout its extent.

By means of an analysis of variance calculation the variation in silt content between six loess profiles was determined. The F value, a measure of this variation, was calculated to be 2.83. This means that at the 1% level, the difference in silt content among all these profiles is not significant.

By comparing the X-ray patterns (figure 8a, b, c) of selected loess horizons representing three profiles from the east, southwest, and north parts of the loess area, it is found that the general configuration of the patterns and the identified mineral species are sufficiently similar to warrant the conclusion that no significant mineralogical difference exists between the locations thus examined. Hence, it is reasonable to assume that the loess is
Fig 8a. X-RAY DIFFRACTION PATTERNS OF THE FINE SILT FRACTION OF SELECTED HORIZONS OF THE SCAPPOOSE 1-5 PROFILE

**"B^2" HORIZON**

**"B_M" HORIZON**

**"D" HORIZON**

"d" SPACING (ANGSTROM)
Fig. 8b. X-RAY DIFFRACTION PATTERNS OF THE FINE SILT FRACTION OF SELECTED HORIZONS OF THE GRESHAM 5-3 PROFILE

"B⁺" HORIZON

"B₂" HORIZON

"O" HORIZON

"O" SPACING (ANGSTROM)

2θ (DEGREE)
Fig. 8c X-ray diffraction patterns of the fine silt fraction of selected horizons of the Chehalis Mts A-14 profile.

- "Bv" Horizon
- "Bw" Horizon
- "D" Horizon

*D* spacing (angstrom) vs. 2θ (degree)
uniform throughout its extent and derived from a common source.

Lack of vertical uniformity within the loess was suggested by mechanical analysis data as shown in cumulative percent curves (figure 4a, b). Curves for upper loess horizons tend to be grouped and distinct from a group of curves from lower loess horizons. This is most obvious for the Gresham 5-3, Chehalem Mountain A-14, Scappoose 1-4, and Scappoose 1-3 profiles. Whittig et al. (57, pp. 228-231) found a discontinuity in mineralogy of a Cascade profile consistent with this grouping of horizons, which they interpreted as a boundary between layers of different age. Assuming that the loess deposit includes layers of different age, horizons of the various profiles may be assigned to the two layers on the basis of mechanical analysis as follows:

<table>
<thead>
<tr>
<th>Profile</th>
<th>Upper Layer</th>
<th>Lower Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gresham</td>
<td>$A_1; A_3; B_1; B_2$</td>
<td>$B_{31}; B_{32}$</td>
</tr>
<tr>
<td>Scappoose 1-4</td>
<td>$A_1; A_3; B_1$</td>
<td>$B_2$</td>
</tr>
<tr>
<td>Scappoose 1-3</td>
<td>$A_1; A_3$</td>
<td>$B_1; B_2$</td>
</tr>
<tr>
<td>Chehalem Mountain A-14</td>
<td>$A_1; A_3; B_1$</td>
<td>$B_2; B_{31}; B_{32}$</td>
</tr>
</tbody>
</table>

The coincidence of the discontinuity in the Cascade profile found independently of mechanical analysis by Whittig with the break indicated by the cumulative percent curves for profile Scappoose 1-5 at a depth of 36 inches, suggests that the groupings of mechanical analysis data, as illustrated above, are meaningful.

The tendency for a systematic grouping of these horizons as shown by mechanical analysis could be interpreted simply as a
consequence of clay accumulation as a result of soil development. However, the discontinuity is not consistent relative to horizon sequence. In the Scappoose l-5 and Gresham 5-3 profiles, for example, the break occurs between two pan horizons. Nevertheless, mechanical analysis data was not considered conclusive, and therefore the idea was further checked by comparisons of the mineralogy of fine silt fractions of two horizons from the profiles Scappoose l-5, Gresham 5-3, and Chehalem Mountain A-14, chosen to represent the supposed upper and lower layers.

Inspection of X-ray diffraction patterns (figure 8a, b, c) of these silt fractions revealed differences in height of quartz peaks between the upper and lower layers of the Scappoose l-5 and the Gresham 5-3 profile, and to a much lesser extent also in the Chehalem Mountain A-14 profile. Quantitative estimates of these differences were obtained in the manner described in the following paragraph.

Klug and Alexander (27, p. 410) state that in powder X-ray diffraction analysis the intensity of the pattern of each component is, except for an absorption correction, proportional to the amount present. Correction for absorption is generally achieved by the use of the internal standard technique; but because in this study relative rather than absolute quantitative differences are sufficient, the quantities of the respective minerals were estimated directly from peak intensities without correcting for absorption. Peak intensities were calculated by subtracting background intensity from total intensity. The two highest quartz peaks at d spacings of
3.35 Å and 4.25 Å respectively and the two highest feldspar peaks with d spacings at 3.20 Å and 4.06 Å respectively were measured. Total intensity values in counts/second were determined by timing the collection of 16,000 counts on duplicate sample mounts. The exact location of each peak was found by hand-scanning. The background intensity for each subsample was averaged from intensities obtained at values of 19 and 29 degree 2θ which bracket the four peaks. Peak intensities are summarized in table 9.

In the case of Scappoose 1-5 and Gresham 5-3 profiles, the intensities of both quartz peaks are considerably greater for the lower horizons than for the upper horizons. The quartz peak intensities for upper and lower layers, however, are almost equal in the Chehalem Mts. profile. These relations tend to confirm the existence of two different layers in the loess deposit.

However, the identity of the layer differing in origin or time of deposition can be evaluated more clearly in terms of quartz to feldspar ratios. Mineral ratios have been used by Vanderford (50, pp. 7-29), Springer (43, pp. 461-467) and Whiteside (56, pp. 415-419) as indexes of weathering. The quartz to feldspar ratios calculated from the peak intensities are summarized in table 10.

The Gresham 5-3 profile is characterized by markedly lower quartz to feldspar ratios in the upper horizon than in the lower. In the Scappoose 1-5 profile the same relationship is to be found, but it is less pronounced. For the Chehalem Mts. A-14 profile the relationship depends on the ratio; two are higher and two are lower
Table 9
Quartz and Feldspar X-ray Diffraction Intensities in Counts per Second for the Fine Silt Fractions of Selected Horizons

<table>
<thead>
<tr>
<th>Table 9</th>
<th>Quartz</th>
<th>Feldspar</th>
<th>Quartz</th>
<th>Feldspar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.35 Å° 425 Å°</td>
<td>3.20 Å° 4.06 Å°</td>
<td>3.35 Å° 4.25 Å°</td>
<td>3.20 Å° 4.06 Å°</td>
</tr>
<tr>
<td>Scappoose 1-5 Profile</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B₂ Horizon (Upper)</td>
<td>B₃₂ Horizon (Lower)</td>
<td>run a 293</td>
<td>74</td>
<td>51</td>
</tr>
<tr>
<td>run b 336</td>
<td>71</td>
<td>46</td>
<td>25</td>
<td>446</td>
</tr>
<tr>
<td>average 315</td>
<td>73</td>
<td>49</td>
<td>28</td>
<td>457</td>
</tr>
<tr>
<td>Gresham 5-3 Profile</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B₂ Horizon (Upper)</td>
<td>B₃₁ Horizon (Lower)</td>
<td>run a 226</td>
<td>63</td>
<td>55</td>
</tr>
<tr>
<td>run b 230</td>
<td>64</td>
<td>50</td>
<td>37</td>
<td>543</td>
</tr>
<tr>
<td>average 228</td>
<td>64</td>
<td>43</td>
<td>43</td>
<td>575</td>
</tr>
<tr>
<td>Chehalem Mountains A-14 Profile</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B₁ Horizon (Upper)</td>
<td>B₂ Horizon (Lower)</td>
<td>run a 363</td>
<td>91</td>
<td>49</td>
</tr>
<tr>
<td>run b 379</td>
<td>94</td>
<td>50</td>
<td>39</td>
<td>383</td>
</tr>
<tr>
<td>average 371</td>
<td>93</td>
<td>50</td>
<td>43</td>
<td>396</td>
</tr>
</tbody>
</table>
Table 10
Quartz/Feldspar Ratios of X-ray Diffraction Intensities for the Silt Fraction of Selected Horizons

<table>
<thead>
<tr>
<th></th>
<th>Quartz 3.35(\AA)</th>
<th>3.35(\AA)</th>
<th>4.25(\AA)</th>
<th>4.25(\AA)</th>
<th>3.35(\AA)</th>
<th>3.35(\AA)</th>
<th>4.25(\AA)</th>
<th>4.25(\AA)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Feldspar 3.20(\AA)</td>
<td>4.06(\AA)</td>
<td>4.06(\AA)</td>
<td>3.20(\AA)</td>
<td>3.20(\AA)</td>
<td>4.06(\AA)</td>
<td>4.06(\AA)</td>
<td>3.20(\AA)</td>
</tr>
<tr>
<td>Scappoose 1-5</td>
<td>B(_2) Horizon (Upper)</td>
<td>6.42 11.25 2.60 1.48</td>
<td>B(_3) Horizon (Lower)</td>
<td>8.46 13.05 2.94 1.90</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gresham 5-3</td>
<td>B(_2) Horizon (Upper)</td>
<td>5.30 5.30 1.48 1.48</td>
<td>B(_3) Horizon (Lower)</td>
<td>13.69 13.37 3.44 3.52</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chehalem</td>
<td>B(_1) Horizon (Upper)</td>
<td>7.42 8.62 2.16 1.86</td>
<td>Mountains A-14</td>
<td>B(_2) Horizon (Lower)</td>
<td>7.07 10.42 2.60 1.76</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
for the upper horizon.

Further comparisons of the X-ray diffraction patterns revealed a difference also in average background between upper and lower layers, similar to the difference in quartz peak intensities and similar to the quartz to feldspar ratios.

The background data obtained in connection with the determination of quartz and feldspar peak intensity rates are shown on table 11. For the Scappoose 1-5 and the Gresham 5-3 profiles, the background is highest for the upper layers and lowest for the lower layers. Both the Chehalem Mts. readings are intermediate.

Klug and Alexander (27, p. 380) state that the presence of uncrystallized or poorly crystallized material in an otherwise crystalline specimen may cause an increase in background and a decrease in Bragg reflection intensity. This by no means accounts for the total background, to which general radiation, absorption discontinuities, air scatter, and secondary fluorescence radiation may also contribute to a greater or lesser extent depending on the material analyzed. However, it may account for differences in background between samples, assuming that everything else remains constant.

Whittig et al. (57, p. 229) report small percentages of glass in the upper horizons of the Cascade profile. The lower horizons, according to the authors, contain very little glass. Differences in content of glass, a noncrystalline material, could perhaps account for the differences in background observed in the two profiles:
### Table 11

X-ray Diffraction Background Intensities in Counts per Second for the Silt Fraction of Selected Profiles

<table>
<thead>
<tr>
<th></th>
<th>Scappoose 1-5 Profile</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Scappoose 1-5 Profile</td>
</tr>
<tr>
<td></td>
<td>B2 Horizon (Upper)</td>
</tr>
<tr>
<td></td>
<td>19°29 29°29</td>
</tr>
<tr>
<td>run a</td>
<td>44 44</td>
</tr>
<tr>
<td>run b</td>
<td>45 44</td>
</tr>
<tr>
<td>average</td>
<td>44 38</td>
</tr>
<tr>
<td></td>
<td>B22 Horizon (Lower)</td>
</tr>
<tr>
<td></td>
<td>19°29 29°29</td>
</tr>
<tr>
<td></td>
<td>run a 38</td>
</tr>
<tr>
<td></td>
<td>run b 37</td>
</tr>
<tr>
<td></td>
<td>average 38</td>
</tr>
</tbody>
</table>

|                      | Gresham 5-3 Profile                                                                    |
|                      | Gresham 5-3 Profile                                                                    |
|                      | B2 Horizon (Upper)                                                                    |
|                      | B21 Horizon (Lower)                                                                    |
| run a                | 48 33                                                                                 |
| run b                | 50 36                                                                                 |
| average              | 49 34                                                                                 |

|                      | Chehalem Mountains A-14 Profile                                                       |
|                      | Chehalem Mountains A-14 Profile                                                       |
|                      | B1 Horizon (Upper)                                                                    |
|                      | B2 Horizon (Lower)                                                                    |
| run a                | 41 41                                                                                 |
| run b                | 41 41                                                                                 |
| average              | 41 41                                                                                 |
Scappoose 1-3 and Gresham 5-3.

In order to test the validity of the above hypothesis, the same fine silt fractions that were analyzed with X-ray and upon which the background data are based were checked with the petrographic microscope by E. G. Knox and J. A. Pomerening. The glass content of all samples seemed to be quite low except for one sample which was slightly higher. Silt size aggregates of clay minerals were identified in variable amounts which correlate with the background readings. The lower layers of the Scappoose 1-5 and Gresham 5-3 profiles revealed low amounts of these minerals, whereas the upper layers showed larger amounts. Both the Chehalem Mountain layers proved to be intermediate in the content of these minerals. This information suggests that the differences in background radiation are not due to differences in glass content, but may be due to differences in amounts of imperfectly crystalline clay aggregates.

All these results show the same relationships. A distinct discontinuity exists in the Gresham 5-3 and the Scappoose 1-5 profiles; however, no detectable discontinuity exists in the Chehalem Mts. profile. If the discontinuity separates loess layers of different age or origin, one of these layers must be missing on Chehalem Mountain. This is conceivable since Chehalem Mts. is much further from the loess source than the other two profile locations.

Yet the identity of distinct loess layers within the deposit is not conclusively established by these results. Analyses of more profiles with more samples from each are needed to establish the
reliability of the findings of this study. The relationships should be particularly evident in the profiles from the deepest part of the deposit.

Morphology and Relationships Among the Soils

The range of morphological characteristics, the topographic positions, and the uniformity of the parent material suggest the catena concept as a possible explanation of the differences among these soils.

The Cascade soil series as illustrated by the description of the Scappoose 1-5 profile is an imperfectly drained soil. The pan in the lower B horizons at a depth of approximately 30 inches is mottled and divided into prisms by gray streaks. It represents the greatest degree of pan development in the whole area.

Profile A-17 on Bull Mountain illustrates a moderately well drained soil. The B₃ horizon at a depth of 25 inches has a pan which is not as well developed as the above. It is firm, but less firm than the Cascade pan. Gray streaks define coarse prisms; yet they are not as well defined as those in the Cascade profile.

Profile A-18 near the Chapman School in Columbia County illustrates the well drained member of the catena. No evidence of a hardpan development exists in this soil.

In the descriptive legend for the Washington Soil Conservation district* three "well drained" soils, an imperfectly drained soil,

and a poorly drained soil developed from wind-worked sediments, have been recognized. The imperfectly drained soil as described in the legend is probably equivalent to the Cascade soil mentioned above. The poorly drained soil has not been observed in the course of this study. Of the "well drained" soils, the D₃ and D₁ as proposed in the legend, compare with the well drained and moderately well drained soils, respectively. The names Laurelwood, Kinton, Cascade, and Delena have been proposed recently* for the well drained, moderately well drained, imperfectly drained, and poorly drained soils respectively.

Most loess soils on Chehalem Mountain, illustrated by profiles A-14 and A-15, fall into the moderately well to well drained parts of the catena.

Soils mapped as Powell on uplands around Portland and south of Gresham in the Multnomah and Clackamas Co. soil surveys (37, pp. 47-98; 29, pp. 1633-1701) are believed to be sufficiently similar to the Cascade soil series to be mapped as such, although some difference exists in the amounts of shot in the topsoil and possibly in the degree to which the pan is developed.

The Powell soils at lower elevations east of Gresham, although morphologically similar to the Powell soils on uplands, may be separated from these if differences in the parent material can be proven to exist. The evidence advanced in this study is suggestive of such differences.

* Personal communication, E. G. Knox, Department of Soils, O.S.C.
The pan horizons of the Cascade soil series and of the soil now called Powell are much like the fragipan horizons described by Carlisle, Grossman, and Knox (10, pp. 320-321) in New York. In both areas pans are brittle, hard or very hard when dry, firm when moist, mottled, and divided into large prisms by gray streaks.

Description of Profile 4-2
An example of the imperfectly drained soil from loess.

This profile was described by Arthur Theisen, August 8, 1956 in Multnomah County, Oregon, Section 10, T. 1N, R. 1W, close to the intersection of the Skyline Boulevard and the Germantown road.

The location was on a 6% northwest slope, at an elevation of approximately 960 feet. The vegetation included Douglas fir, big leaf maple, vine maple, alder, scotch broom, red huckleberry, and fern. The profile was imperfectly drained and there was no evidence of erosion.

A₁ 0-2.5" Dark brown (10 YR 3/4) silt loam when moist; moderate very fine and fine granular, non sticky and slightly plastic, very friable; abundant shot; gradual and smooth boundary.

A₃ 2.5-8" Very dark gray brown to dark brown (10 YR 3/2 to 10 YR 3/3) silt loam when moist; moderate fine angular to subangular blocky; non sticky and slightly plastic, friable; common shot; gradual and smooth boundary.

B₁ 8-14" Dark brown (10 YR 4/3) silty clay loam when moist; strong fine angular blocky; slightly sticky, plastic,
friable; few shot; gradual and smooth boundary.

**B₂** 14-24"

Yellowish brown (10 YR 5/4 ground mass), light gray (10 YR 7/2 coatings) silty clay loam; weak coarse prismatic breaking to moderate fine angular blocky; slightly sticky and slightly plastic, firm; common manganese dioxide stains; clay flows on ped surfaces; gradual and smooth boundary.

**B₃₁** 24-34

Dark gray brown (10 YR 4/2 ground mass), light gray (10 YR 7/2 coatings) and dark yellowish brown (10 YR 3/4, clay flows) silty clay loam; weak coarse prismatic breaking to moderate medium angular blocky; sticky and slightly plastic, firm; prominent clay flows; gradual and smooth boundary.

**B₃₂** 34-64"

Yellowish brown (10 YR 5/4 ground mass), light brownish gray (10 YR 6/2 coatings) silty clay loam to clay loam; weak coarse prismatic breaking to fine angular blocky; slightly sticky, slightly plastic; firm; mica flakes present, prominent clay flows; gradual and smooth boundary.

**B₃₃** 64-106"

Yellowish brown (10 YR 5/4 ground mass), light brownish gray (10 YR 6/2 coatings) silty clay loam; very coarse prismatic breaking to moderate fine angular blocky; slightly sticky, slightly plastic; friable to slightly firm; prominent clay flows; gradual and smooth.
C₁ 106-126" Yellowish brown (10 YR 5/4 ground mass) pale brown (10 YR 6/3 streaks) silty clay loam; moderate fine angular blocky; slightly sticky, slightly plastic; friable to slightly firm, few clay flows; gradual and smooth boundary.

C₂ 126-152" Yellowish brown (10 YR 5/4 ground mass), pale brown (10 YR 6/3 streaks) silt loam; weak fine angular to sub angular blocky; non sticky and slightly plastic; friable; few thin clay flows.

Description of Profile A-18

An example of the well drained soil from loess.

This profile was described by Ellis Knox and Arthur Theisen July 23, 1957 in Columbia County, Oregon, Section 20 T. 4N, R 2W, in a road-cut on a logging road.

The profile was on a 15% northwest slope. The vegetation included Douglas fir, alder, ferns, Oregon grape, black-berries, etc.

A₁₁ 0-2" Gray brown (10 YR 5/2) silt loam, very dark gray brown (10 YR 3/2) moist; strong very fine granular; non sticky and non-plastic; soft; common shot; abundant roots; smooth and clear boundary.

A₁₂ 2-6" Brown (10 YR 5/3) silt loam, dark brown (10 YR 3/3) moist; moderate to strong fine subangular blocky; slightly sticky and slightly plastic; soft; silty coatings on peds; few fine pores; few concretions; gradual and smooth boundary.
B2  6-32"  Brown to dark brown (7.5 YR 4/4) silt loam, moist; moderate to strong fine subangular blocky; slightly sticky and slightly plastic, friable; nearly continuous thin clay flows, silty coatings in places; few fine pores; gradual and smooth boundary.

B3  32-52"  Dark yellowish brown (10 YR 4/4 ground mass) and brown to dark brown (7.5 YR 4/4 clay flows) silt loam, moist, weak coarse and medium subangular blocky breaking into weak fine angular blocky; slightly sticky and slightly plastic, friable to firm; thin patchy clay flows on peds and in pores; few fine pores, smooth and clear boundary.

D1  52-80"  Dark reddish brown (5 YR 3/4) clay loam, moist; weak coarse subangular blocky; sticky and plastic, very firm; few thin patchy clay flows; gradual and smooth boundary.

D2  80" +  Dark reddish brown (2.5 YR 3/4) clay, moist; sticky and plastic; many rock fragments.

Description of Profile A-17

An example of the moderately well drained soil from loess.

This profile was described by Ellis Knox and Arthur Theisen July 23, 1957 in Washington County, Oregon, NW 1/4, SW 1/4, Section 9, T 2S, R 1W, in a road-cut.

The location was on a 10% southwest slope at approximately 600 feet elevation. The field above the road cut was cultivated.
Ap 0-8" Pale brown (10 YR 6/3) silt loam, dark gray brown (10 YR 4/2) moist; weak medium platy; few fine pores; few fine to medium spherical concretions; slightly sticky and slightly plastic, slightly hard; gradual and smooth boundary.

B1 8-15" Dark brown (7.5 YR 4/4) and light brown (7.5 YR 6/4) silt loam, dark brown (7.5 YR 4/3) moist; moderately thick platy breaking into weak fine angular blocky; slightly sticky and slightly plastic, slightly hard; few thin patchy clay flows and silty coatings; few fine pores; gradual and smooth boundary.

B2 15-25" Brown (10 YR 5/3) silty clay loam, dark brown (10 YR 3.5/3) moist; weak coarse prismatic breaking to strong fine angular blocky; sticky and plastic; firm when moist, hard when dry; continuous clay flows; gradual and smooth boundary.

B3 25-45" + Dark yellowish brown (10 YR 4/4 ground mass), dark brown (10 YR 3/3 clay flows), brown (10 YR 5/3 streaks), and strong brown (7.5 YR 5/6 mottles in streaks) silty clay loam, moist. Ground-mass weak very coarse prismatic, breaking to moderate very coarse angular blocky, breaking in turn to weak medium angular blocky; streaks define very coarse prisms; firm except for streaks; sticky and plastic; clay flows continuous on very coarse blocks, patchy
on medium blocks; few roots; common fine pores.

Origin of the Material

The thinning of the loess deposit with distance from the Columbia River indicates that the Columbia River floodplain was the loess source. The thinning in depth and width of the deposit to the north and to the east away from the deepest and widest part in the vicinity of Portland (figure 5 and 6), suggests that the river floodplain north of Portland was the most important part of the source. The length and width of the present Columbia River floodplain and terraces is consistent with this assumption. The loess deposit must be Pleistocene age or younger since the oldest terrace remnants of the Columbia River floodplains are Pleistocene (9, pp. 11-26; 20, p. 841; 47, p. 2034) and the youngest rock found under the loess is Boring lava, reported by Treasher and Schlicker (48, map; 38, p. 86) as intermediary between Pliocene and Pleistocene. Conditions were favorable for the origin of loess during the "Spokane flood" in the Pleistocene.

The Spokane flood, whether it was one big event, or is composed of a large number of floods (7, pp. 249-252; 2, pp. 675-722), was produced without doubt by glacial melt waters. This fact puts the event in the Wisconsin glacial stage if Flint (14, pp. 215-217) is correct in assuming that the bulk of the Cordilleran glaciation occurred in Wisconsin age.

There is little doubt that the Columbia waters of that time carried a considerable load of gravels, sands, and silts. This is
evidenced by alluvial material 350 feet deep in the Portland floodplain deposited by the ancestral Columbia River in the form of a subaqueous delta, as postulated by Bretz (7, pp. 249-252), or deposited as river sediments by the Columbia after its entrenchment in the gorge as suggested by Allen (1, pp. 86-92) and Hodge (20, pp. 831-930).

During the Wisconsin ice age favorable conditions for strong north east winds existed. It is just these winds that are required to blow the silts from the Portland floodplains into the uplands where the deepest deposits are now found. These winds could have originated from the edges of the continental ice sheet, which is reported to have reached as far south as Mt. Adams by Flint (14, p. 216). Such winds, called anticyclonic winds, were first described by Hobbs (19, pp. 381-385) in a remarkable study of the glacial outwash of the Greenland continental glacier. They have been further recognized by Antevs (4, pp. 172-176), Bryan (8, p. 245), and Obruchev (35, p. 257), among others.

The several stages of glaciation mentioned by Hodge (20, p. 841) and Bretz (6, pp. 9-244) might be considered, at least in part, as substages of the Wisconsin ice age. If periods of relatively warm or interglacial substages can account for the flooding and for concurrent deposition of sediments by the Columbia River, then the subsequent colder periods or glacial substages can bring about the necessary conditions for redeposition of the finer sediments by wind action. If several such substages followed each other one might even
assume that the two distinct superimposed loess layers are due to two consecutive glacial substages of the Wisconsin glacial stage. A detailed study of the deeper loess deposits around the city of Portland might reveal the presence of more than two distinct layers and could even lead to a better understanding of the Wisconsin glacial stage as such.

The presence of at least traces of volcanic glass in the loess profiles can suitably be explained by volcanic activity that existed during the later Pleistocene in the Cascade Range. Verhoogen (51, p. 265) states that Mt. St. Helens in the southwestern part of Washington started to build up lava flows at the close of the glacial epoch. Little doubt remains that large quantities of volcanic fall-out were associated with this volcanic activity. Mt. Hood is believed to have erupted intermittently during the glacial stages of the Pleistocene, and showers of ash are believed to be associated with these eruptions (1, pp. 86-92). In addition to these local sources of volcanic ash, it is entirely possible that the alluvial material deposited by the Columbia River could have contained volcanic ash that was redeposited by the winds as loess.
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