Series 1937, No. 2 Issued March 1948

Soil Survey

The Umatilla Area Oregon

By
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UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Administration
Bureau of Plant Industry, Soils, and Agricultural Engineering
In cooperation with the
OREGON AGRICULTURAL EXPERIMENT STATION

HOW TO USE THE SOIL SURVEY REPORT

SOIL SURVEYS PROVIDE a foundation for all land-use programs. The report on each survey and the map that accompanies the report present information, both general and specific, about the soils, the crops, and the agriculture of the area surveyed. The individual reader may be interested in the whole report or only in some particular part. Ordinarily he will be able to obtain the information he needs without reading the whole. Prepared for both general and detailed use, the report is designed to meet the needs of a wide variety of readers of three general groups: (*a*) Those interested in the area as a whole; (*b*) those interested in specific parts of it; and (*c*) students and teachers of soil science and related agricultural subjects. Attempt has been made to meet the needs of all three groups by making the report comprehensive for purposes of reference.

Readers interested in the area as a whole include those concerned with general land use planning—the placement and development of highways, power lines, docks, urban sites, industries, community cooperatives, resettlement projects, and areas for private or public forests, recreation, and wildlife management. The following sections are intended for such users: (*a*) General Nature of the Area, in which physiography, relief, drainage, climate, water supply, vegetation, history, population, industries, transportation, markets, and cultural developments are discussed; (*b*) Agriculture, in which a brief history of the agriculture is given and the present agriculture described; (*c*) Productivity Ratings and Land Classification, in which the productivity of the soils is given and a grouping of soils presented according to their relative physical suitability for agricultural use; and (*d*) Land Use and Soil Management, in which the present use of the soils is described, their management requirements are discussed, and suggestions made for improvement in management.

Readers interested chiefly in specific areas—such as some particular locality, farm, or field—include farmers, agricultural technicians interested in planning operations in communities or on individual farms, and real estate agents, land appraisers, prospective purchasers and tenants, and farm loan agencies. The reader's first step is to locate on the map the tract with which he is concerned. The second is to identify the soils on the tract by locating in the legend on the margin of the map the symbols and colors that represent them. The third step is to locate in the table of contents in the section on Soils the page where each type is described in detail and information given as to its suitability for use and its relations to crops and agriculture. He will also find useful specific information relating to the soils in the section on Productivity Ratings and Land Classification and on Land Use and Soil Management.

Students and teachers of soil science and allied subjects, including crop production, forestry, animal husbandry, economics, rural sociology, geography, and geology, will find their special interest in the section on Morphology and Genesis of Soils. They will also find useful information in the section on Soils, in which is presented the general scheme of classification of the soils of the area and a detailed discussion of each type. For those not already familiar with the classification and mapping of soils, these subjects are discussed under Soil Survey Methods and Definitions. Teachers of other subjects will find the sections on General Nature of the Area, Agriculture, Productivity Ratings and Land Classification, and the first part of the section on Soils of particular value in determining the relations between their special subjects and the soils in the area.

This publication on the soil survey of the Umatilla area, Oreg., is a cooperative contribution from the—

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Series 1937, No. 21 Issued March 1948

SOIL SURVEY OF THE UMATILLA AREA, OREGON

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United States Department of Agriculture in cooperation with the Oregon Agricultural Experiment Station

CONTENTS

THE Umatilla area is within the Columbia Plateaus physiographic province. The original agricultural activities there consisted of raising a small acreage of maize and other edible seeds by the Indians. The early white settlers were interested chiefly in producing the crops

[1] The field work for this survey was done while the Division of Soil Survey was a part of the Bureau of Chemistry and Soils.

necessary to supply the needs of gold miners, and most of the agriculture consisted of stock raising. Today wheat, barley, oats, and hay are the principal crops and sheep and cattle the chief livestock. Dairying and potato growing are important in irrigated districts, and timbered areas are in the Blue Mountains, where rainfall is abundant. Pendleton is an important shipping point for livestock and grain and furnishes employment for many in the flour mills, creameries, elevators, cannery, brewery, woolen mill, and saddle factory. Other towns are important cattle, grain, and timber-marketing centers. To provide a basis for the best agricultural uses of the land a cooperative soil survey was begun in 1937 by the United States Department of Agriculture and the Oregon Agricultural Experiment Station. The essential features may be summarized as follows.

SUMMARY

The Umatilla area is in northeastern Oregon and includes practically all the cultivated land as well as extensive areas of grass-covered livestock range and of forest in Umatilla County. Extending from the Columbia River into the Blue Mountains, it includes extensive plains, high smooth-topped terraces, higher plateaus or mountains, and timber-covered ridges; and smaller areas of bottom lands, low terraces, alluvial fans, steep mountain slopes, cliffs, and canyons. Almost the entire area is naturally well drained, but owing partly to seepage from irrigation, several soils are now poorly drained and are affected by accumulations of soluble salts (alkali).

The present-day agriculture of the greater part of the area consists of growing wheat, which is the most important dry-farming crop. In and near the foothills and in the lower mountain belt the production of peas for canning is important, and barley, potatoes, clover, oats, and rye are grown by dry-farming methods. Raising sheep and beef cattle and dairying are important industries, and in irrigated sections alfalfa hay, corn, fruits, and vegetables are important crops. Other than for pasture, the steep and mountainous districts are valuable for timber, which is marketed as lumber or fuel.

Practically the entire area is underlain by basaltic bedrock. The soil material that has accumulated above the rock in most places has probably been deposited largely by the wind, but in the valleys and on some of the lower plains much of it has been deposited by streams or lake waters. On steep slopes, particularly in the foothills and mountains where conditions have not been favorable for the accumulation of soil materials, the thin layer of soil over bedrock has in places come largely from the breaking down of the rock.

The 59 soils and 6 miscellaneous land types recognized have a wide range in characteristics, although over considerable areas they are fairly uniform. These 65 units belong to 7 large groups as follows: (1) Medium- to dark-colored soils of the smooth to rolling loessal plains of the great central wheat belt—the Athena, Walla Walla, Pilot Rock, Morrow, and McKay series; (2) light-colored soils of the smooth to rolling plains and lake terraces—the Ritzville, Sagemoor, and Burke series; (3) dark-colored soils of the foothills and lower mountains—the Palouse, Waha, and Thatuna series; (4) light-colored soils of the Blue Mountains—the Helmer and Couse series; (5) light-colored sandy soils of the Columbia River terraces—the Quincy, Ephrata, Rupert, and Winchester series; (6) soils of the bottom lands and low

terraces—the Snow, Caldwell, Hermiston, Onyx, Yakima, Stanfield, and Umapine series; and (7) the Waha, Underwood, and other miscellaneous nonarable soils and land types.

The soils are used as follows: First group, mostly for growing wheat under dry-farming methods, including summer fallow in alternate years; second group, for dry-farmed wheat, livestock range, and for alfalfa and other crops under irrigation; third group, for growing wheat and peas, with potatoes where the rainfall is more abundant; fourth group, for timber, with some potatoes, berries, oats, timothy, and red clover in places; fifth group, for livestock range and for alfalfa, corn, and other crops under irrigation; sixth group, for a wide variety of crops, mostly under irrigation; and seventh group, largely for livestock range, with some timber in the mountains.

No great expansion of agriculture is probable in the Umatilla area, although the irrigated acreage may be somewhat increased and some of the soils in the Blue Mountains may be made more productive by liming and fertilization. Productivity of the dry-farmed areas probably can be maintained better if straw and stubble are plowed under rather than burned and if care is taken to minimize runoff and erosion. A large part of the irrigated acreage is used for the production of alfalfa and pasture. Other important irrigated crops include corn, prunes, apples, cherries, potatoes, melons, tomatoes, and other garden crops. Drainage of wet land and washing out of the excess of soluble salts (alkali) are essential in some of the irrigated areas.

The great soil groups are represented in the uplands, from the lower northwest to the mountainous southeast, by the Sierozem, Brown, Chestnut, Chernozem, Prairie, and Podzol soils. On bottom lands and low terraces a number of azonal and intrazonal soils have been developed largely from alluvial materials, with a large proportion of loess.

GENERAL NATURE OF THE AREA

LOCATION AND EXTENT

The Umatilla area, in northeastern Oregon (fig. 1), covers nearly 60 percent of Umatilla County, including nearly all the cultivated land but excluding mountainous parts in the southern end and along the eastern border. Covering a total of 1,872 square miles (1,198,080 acres), it extends about 40 miles southward and eastward from the Columbia River, across the plain and into the Blue Mountains. The Oregon-Washington State line forms its northern, and the Columbia River its northwestern boundary. Pendleton, the county seat, which is near the center of the area, is 190 miles from Portland and 215 miles from Salem.

PHYSIOGRAPHY, RELIEF, AND DRAINAGE

The Umatilla area is entirely in the Columbia Plateaus physiographic province.[2] It consists essentially of a smooth to rolling plain and a higher plateau—the Blue Mountain section. The northwestern part of the plain consists of a series of old terraces of the Columbia River, which rise from about 250 feet above sea level at the northwestern corner to more than 800 feet about 16 miles to the southeast.

[2] FENNEMAN, N. M. MAP OF THE PHYSICAL DIVISIONS OF THE UNITED STATES. U. S. Geol Survey. 1930.

These terraces form smooth to gently rolling plains, broken occasionally by wind-blown hummocks. Above them the lava-floored (basaltic) plain rises gradually to the south and east to the slopes at the foot of the Blue Mountains, where the elevation ranges from 1,500 to 2,000 feet or more above sea level (pl. 1). The Blue Mountains, which attain an elevation of more than 4,000 feet within the area, are in reality a high plateau that drops off rather steeply (1,500 to 2,000 feet in about 3 miles) on the northwest and is deeply cut by V-shaped canyons, leaving comparatively smooth ridge tops varying in width from a few hundred yards to 2 miles or more. Similar canyons are

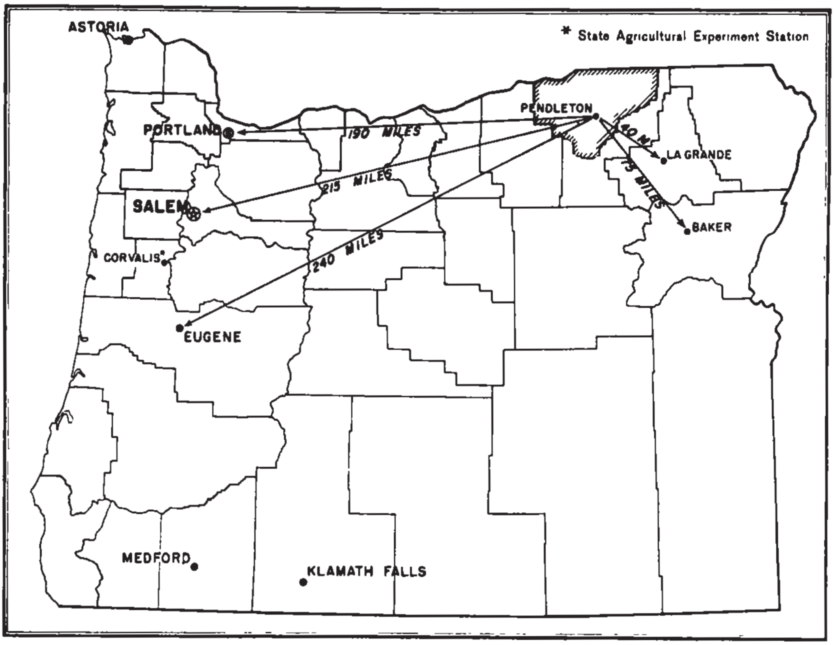
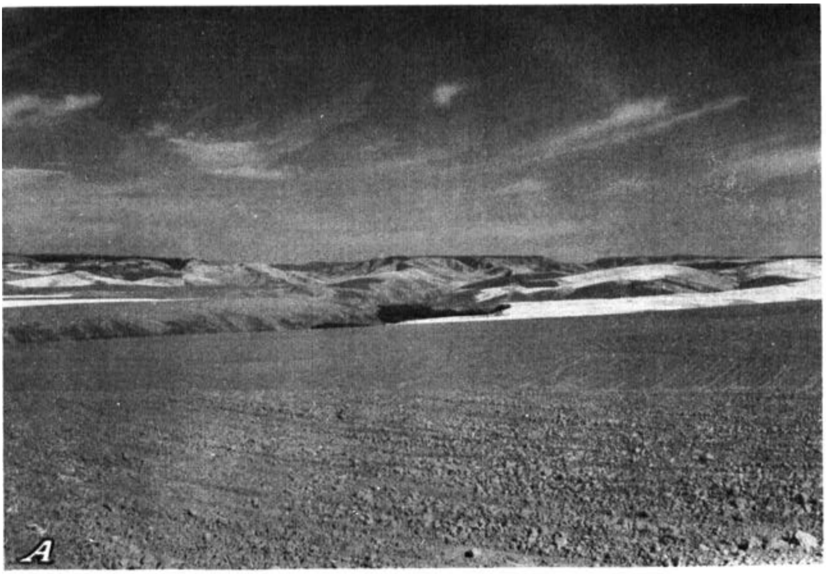


FIGURE 1.—Location of the Umatilla area in Oregon.

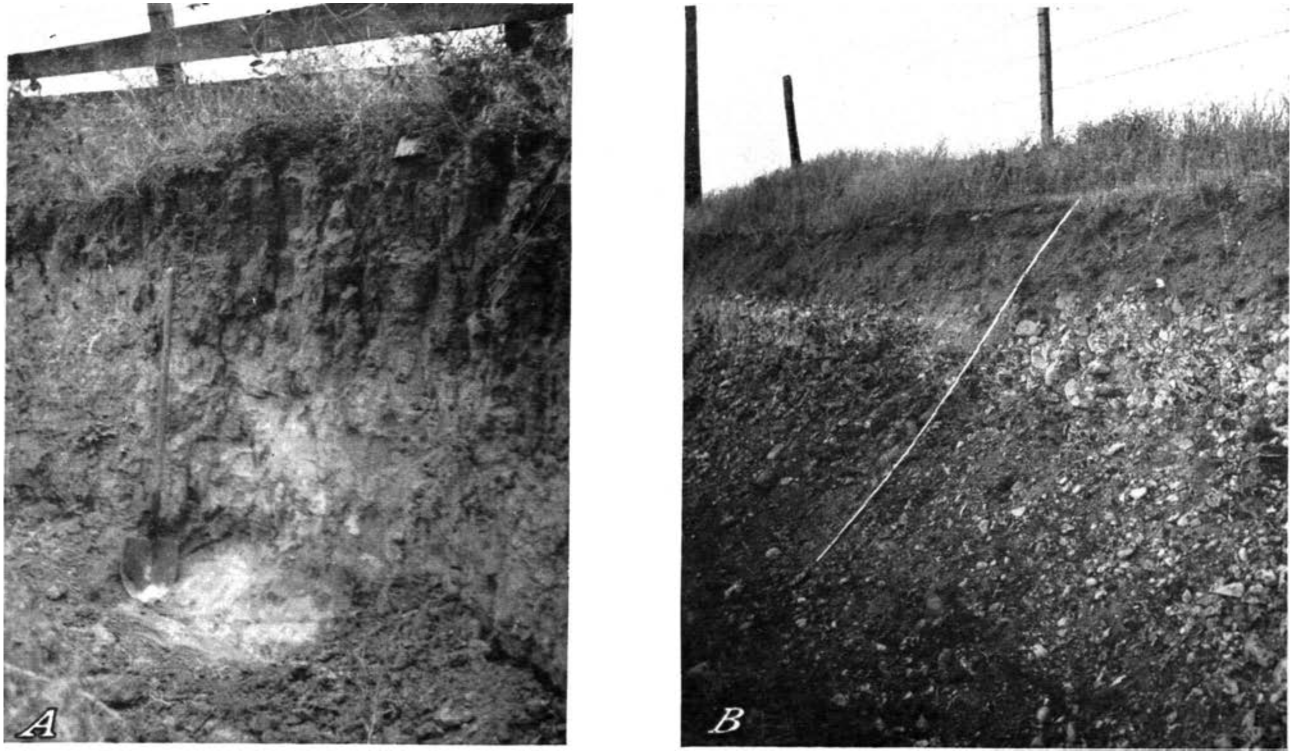
cut through the plain, but they are not so deep or so wide and the uplands between them are much wider.

The Walla Walla Valley extends from the northeastern part of the area into the State of Washington. It is a lowland, almost 40 square miles of which lies on the Oregon side of the line, and is made up of bottom lands, smooth gently sloping alluvial fans, and low terraces. Many erosional remnants of a former higher plain now form ridges and terraces at an elevation of a few feet to 50 feet or more above the bottom lands. The valley is bounded on the southwest by an escarpment, or series of bluffs, rising as much as 1,300 feet above the valley and on the east by a bluff 50 feet or more in height. Other less extensive alluvial valleys or bottom lands border the Umatilla River and a number of its tributaries—Butter, Birch, McKay, and Wildhorse Creeks. The Umatilla River bottom lands are nearly 3 miles wide west of Stanfield and northwest of Echo.

The upland plains vary considerably in elevation and relief, some sections being fairly smooth and others strongly rolling and severely dissected. That part of the area southwest of Pendleton and west of



A, Summer fallow and wheat stubble on Walla Walla silt loam. Blue Mountains in the background. Athena, Palouse, and Waha soils occupy the lower slopes. *B*, View looking up the canyon of the South Fork of Cottonwood Creek east of Milton in the foothills of the Blue Mountains, showing steep and barren west and southwest slopes, typical rough stony land, and a thick stand of timber on the north slope and on the high plateau top.



A, Profile of Athena silt loam, showing deep dark surface soil, prismatic structure, and light-colored lime layer (at right of shovel blade.) *B*, Profile of Pilot Rock silt loam, showing the thin soil over a substratum of lime-cemented gravel.

Pilot Rock is one of the most rolling sections, and that around Juniper Canyon, Holdman, and Van Sycle is also strongly rolling; but most of the rest of the upland plains are undulating to gently rolling. South of the Umatilla Indian Agency and east of McKay Lake is one of the smoothest areas, consisting of a series of gently sloping alluvial fans lying at the foot of the Blue Mountains.

The elevations[3] range from about 250 feet on the Columbia River below Umatilla to about 4,000 feet in the Blue Mountains east of Weston. The altitudes of some of the towns are as follows: Umatilla, 296 feet above sea level; Hermiston, 450 feet; Echo, 601 feet; and Pendleton, 1,100 feet. On the Walla Walla River at Milton the elevation is 1,100 feet. In the upland plains the elevation of Helix is about 1,750 feet; Adams, 1,526 feet; and Weston, 1,800 feet.

All the Umatilla area drains into the Columbia River, and nearly all has a well-developed natural drainage system. The Umatilla River, together with its tributaries, forms a dendritic (tree-shaped) stream system that drains most of the area. The Walla Walla River, which flows into the State of Washington, forms the drainage outlet for about 200 square miles of the northeast. A few canyons in the northwest, which have drainage basins ranging from 10 to 50 square miles or more, empty directly into the Columbia River. In the lower lying parts the river and stream bottoms are only a few feet below the general level of the land, but in places amid the rolling plains the streams have cut channels 50 to 300 feet or more deep, and in the mountains some canyons are more than 1,500 feet deep. Along some of the drainage channels the slopes average less than 15 percent, though in the mountainous districts and in the northwestern and north-central parts, many are more than 40 percent. The Columbia River itself flows through a basaltic box canyon that is nearly 1,000 feet deep at the point where it cuts across the Oregon-Washington State line, but it gradually becomes shallower and above Umatilla it opens into a shallow valley.

CLIMATE

The climate of the Umatilla area is, in general, temperate and semiarid, although great differences in temperature and rainfall occur between the higher and lower parts. The climate is of the continental type, characterized by considerable daily and yearly temperature ranges, but apparently is tempered to some extent by winds from the Pacific Ocean. It is considerably milder than in areas of the same latitudes east of the Rocky Mountains, and cold waves are not often severe. The Coast and Cascade Ranges, to the west, rob the prevailing westerly winds of much of their moisture, and as a result the climate is much dryer than in western Oregon and is also characterized by greater extremes of temperature. The relative humidity for the year is low, and the average number of hours of sunshine is greater than in the east and along the Pacific coast. The summers are warm, and a few days have temperatures above 100° F., but these hotter periods are not oppressive, because of the low humidity. Although the winters are comparatively mild, freezing temperatures are common throughout most of December, January, and February, and temperatures of 20° below zero or lower have been recorded at Pendleton. In the mountainous districts, winter weather is more severe and much

[3] Elevations obtained from the U. S. Geological Survey topographic maps and from the records of the U. S. Weather Bureau.

lower temperatures are general. At Meacham, which is only a few miles from the area, a temperature of 51° below zero was recorded in 1933. Periods of below-zero weather usually persist only a few days, after which moderating winds warmed by the waters of the Pacific Ocean blow in from the west.

Rainfall comes principally from moisture-laden winds that blow inland from the ocean. Total rainfall is light in all lower lying districts, although beneficial rains occur during the earlier part of the growing season. Precipitation occurs mostly in fall, winter, and spring. Summers are dry, with the period of lowest rainfall during the season of wheat harvest in July and August. Comparatively heavy rains are general over most of the area at times, but at others most of the moisture falls in the mountainous districts. As moisture-laden winds reach the Blue Mountains in the eastern and southern part, they are cooled and drop much of their moisture. The average annual precipitation ranges from about 42 inches in the higher mountains to 7.57 inches at Umatilla. The distribution of rainfall and the range in temperature correspond very closely with elevation and nearness to the mountains. The mean annual temperature at Meacham, 3,700 feet above sea level in the Blue Mountains, is 41.0° F.; at Weston, 1,800 feet, 50.2°; and at Umatilla, 285 feet, 54.3°.

Table 1 gives the elevation, frost-free period, mean annual precipitation, and average snowfall for a number of Weather Bureau stations in Umatilla County.

TABLE 1.—*Elevation, average frost-free season, mean annual precipitation, and average snowfall at various stations in Umatilla County, Oreg.*

Station	Elevation	Average length of frost-free season	Mean annual precipitation	Average snowfall
	Feet	*Days*	*Inches*	*Inches*
Meacham	3,700	(1)	38.16	121.5
Pilot Rock	1,817	[2] 174	13.42	25.8
Weston	1,800	[3] 166	21.51	37.0
Pendleton	1,488	[4] 160	14.08	21.4
Milton	1,100	[5] 193	14.28	19.8
Echo	601	[6] 174	10.02	17.2
Hermiston	451	[7] 169	8.25	13.6
Umatilla	285	[5] 199	7.57	5.3
Blue Mountain Sawmill [9]	4,200		[10] 42.75	[10] 177.6

[1] Killing frosts practically every month.
[2] 31-year record.
[3] 48-year record.
[4] 51-year record.
[5] 26-year record.
[6] 36-year record.
[7] 35-year record.
[8] 38-year record.
[9] About 1 mile east of margin of area east of Weston.
[10] Records kept from 1908–17.

The data in table 1 reflect the influence of the mountains and elevation upon rainfall and temperature. Temperature, rainfall, and length of growing season are of great importance in determining type of farming, kinds and varieties of crops grown, and dates of seeding. At comparatively low elevations in the western part of the area and on open leachy soils, the rainfall is not sufficient to produce crops by dry-farming methods, and in some such places the land is irrigated.

Very seldom are weather conditions unfavorable for farm work, although occasionally the rainfall is so meager in fall that most farmers delay planting wheat until spring, when moisture conditions are more favorable. Dust storms are common in March, April, and

May, and in the western and northwestern parts they hinder farm work and cause considerable blowing of the lighter textured soils.

Table 2, compiled from records of the United States Weather Bureau station at Weston in the eastern part, and at Umatilla in the western part, includes data on the normal monthly, seasonal, and annual temperature and precipitation, which are fairly representative of conditions in the Umatilla area.

TABLE 2.—*Normal monthly, seasonal, and annual temperature and precipitation at stations in Umatilla County, Oreg.*[1]

WESTON, ELEVATION 1,800 FEET

Month	Temperature			Precipitation			
	Mean	Absolute maximum	Absolute minimum	Mean	Total for the driest year	Total for the wettest year	Average snowfall
	°F	°F	°F	*Inches*	*Inches*	*Inches*	*Inches*
December	34 0	67	−23	2 34	1 52	2 47	7.0
January	31 6	69	−22	2 35	1 46	4 15	12 4
February	34 7	68	−16	2 26	1 09	5 61	8 9
Winter	33 4	69	−23	6 95	4 07	12 23	28 3
March	42 5	78	−4	2 46	63	3 27	3 7
April	49 7	94	17	1 90	2 83	2 78	8
May	56 1	97	23	1 99	57	3 03	.1
Spring	49 4	97	−4	6 35	4 03	9 08	4 6
June	62 1	102	29	1 33	70	82	(2)
July	70 0	109	36	42	.10	04	0
August	69 3	110	33	65	24	3 26	0
Summer	67 1	110	29	2 40	1 04	4 12	(2)
September	60 6	99	20	1 30	15	1 79	(2)
October	51 2	89	11	1 76	2 17	2 91	.2
November	40 6	78	−15	2 75	66	3 62	3 9
Fall	50 8	99	−15	5 81	2 98	8 32	4 1
Year	50 2	[3] 110	[4] −23	21 51	[5] 12 12	[6] 33 75	37 0

UMATILLA, ELEVATION 285 FEET

Month	Mean	Absolute maximum	Absolute minimum	Mean	Total for the driest year	Total for the wettest year	Average snowfall
December	34 8	71	−17	0 92	0 73	0 45	0 8
January	33.0	71	−23	1 06	.10	2 45	2 2
February	38 0	78	−1	.81	35	1 92	1 7
Winter	35.3	78	−23	2 79	1 18	4 82	4 7
March	47 4	85	11	60	.40	.44	(2)
April	54 8	97	20	51	.40	.89	(2)
May	62 2	101	30	56	.09	.06	0
Spring	54.8	101	11	1 67	89	1 39	(2)
June	69.6	110	35	45	19	.96	0
July	76 2	115	46	.12	(2)	.53	0
August	74 4	110	37	.32	07	.73	0
Summer	73 4	115	35	89	.26	2 22	0
September	65 0	103	25	.45	36	.74	0
October	54 0	90	21	.65	.43	1 54	0
November	42 2	80	9	1 12	95	.98	.6
Fall	53 7	103	9	2 22	1 74	3 26	.6
Year	54 3	[7] 115	[8] −23	7.57	[9] 4 07	[10] 11 69	5.3

[1] Data from U. S. Weather Bureau
[2] Trace.
[3] 1898.
[4] 1919
[5] 1935.
[6] 1899.
[7] 1931.
[8] 1909.
[9] 1934.
[10] 1881.

VEGETATION

When settlement began in Umatilla County the plains and mountain slopes were covered with luxuriant bunchgrass and the open parks in the timbered area with a variety of other grasses. The valley lands were clothed with giant ryegrass that stood 3 to 6 feet high. The timbered parts were not very different from those that exist at present, though in the pine belt, mainly east of Weston, many areas have been cleared and are now used for growing a variety of crops. Timbered areas occur in the Blue Mountains, where rainfall is abundant. The slopes and ridge tops at intermediate elevations and higher lying rocky or thinly soil covered southern exposures support comparatively open stands of western yellow pine (*Pinus ponderosa* Laws.), whereas on the higher lands or north slopes, where the soil is deeper and more moisture is available, there are rather dense stands of Douglas-fir (*Pseudotsuga taxifolia* (Poir.) Britton), white fir (*Abies concolor* (Gord.) Engelm.), spruce (*Picea* sp.), and tamarack (*Larix occidentalis* Nutt.).

Most of the plains have been plowed and are now used for growing wheat. Many of the drier sections that were cultivated during World War I have since been abandoned and are now used only for grazing. The bunchgrasses did not come back when the cultivated areas were abandoned but have been replaced by downy bromegrass, or downy chess (*Bromus tectorum* L.), which is very inferior to bunchgrass for range purposes, and by big Russian-thistle (*Salsola kali* var. *tenuifolia* Tausch.), mustard (*Brassica* sp.), and other weeds. The principal vegetation of these lands as well as lands that have been overgrazed is downy bromegrass, with a sparse stand of rabbitbrush (*Chrysothamnus* sp.). Sagebrush (*Artemsia* sp.) grows 1 to 2 feet tall on ridges and slopes in the drier parts, but in valley bottoms where more moisture is available it is often 6 feet high or more. Little or no rabbitbrush or sagebrush grew on those lands when the country was first settled by white people. Downy bromegrass has become the dominant grass within the past 30 years.

HISTORY, POPULATION, AND TOWNS

In 1847 an Indian mission was established on the Umatilla River near the present site of Pendleton, and just 2 days later the Whitman party was massacred near the present city of Walla Walla, Wash. Owing to hostility of the Indians, the mission near Pendleton was abandoned after a few months. In 1851 a settlement and an Indian agency were established near Echo. Other settlements were made near the mouth of McKay Creek and in the Walla Walla Valley near Umapine. Some of these settlements were destroyed during the Indian-war period 1855–57. In the fall of 1857 new settlements were made at the mouth of Birch Creek, and in 1860 the first white settlement above Milton was established. Following the discovery of gold at Boise, Idaho, many people passed through this section in 1861, and in 1863 when gold was being mined in Powder River Valley many settlements were made along the Umatilla and Walla Walla Rivers. The early settlers in these valleys were interested principally in raising cattle, sheep, and supplies for the needs of the miners. The settlers came from eastern and southeastern States, and at present nearly all the people are American-born whites.

In 1862 an area was taken from Wasco County to form Umatilla County, in 1885 a part of the new county was taken to form Morrow County and part of Gilliam County, and in 1913 part was annexed to Union County and part of Union County was annexed to Umatilla County. In 1940 the population of the county was 26,030. Pendleton, the county seat, with a population of 8,847, is in the center of the wheat belt and the most important trading and school center in the area. It is an important shipping point for cattle, sheep, wheat, flour, and other grains and has three flour mills, two elevators, creameries, a cannery, a woolen mill, a brewery, and a saddle factory. Milton, population 1,744, and Freewater, 825, are twin towns that form an important trading center and shipping point for the surrounding irrigated district and for the wheat-raising and cattle and timber sections in the northeastern part. These towns have several fruit-packing companies, a flour mill, a sawmill and box factory, a cannery, a creamery, and a vinegar factory with pickling works. Hermiston, in the irrigated section in the northwestern part of the area, with a population of 803, is the most important town in that part. Alfalfa hay, fruit, and turkeys are shipped from it, and a creamery and a cannery are operated there. Pilot Rock, population 358, and Weston, 498, are grain, cattle, and timber-marketing centers. Logs from the timbered areas to the south are hauled by truck to Pilot Rock and to Pendleton, where they are milled or shipped by rail to other milling centers. Two small sawmills are located at Weston. Athena probably ships more wheat than any of the other towns and also has a cannery. Other agricultural marketing and school towns include Umatilla, Stanfield, Echo, Helix, Adams, and Umapine. Rieth is a railway division point. Railway sidings for elevators and loading grain are at Blue Mountain, Mission, Havana, Blakeley, Saxe, Waterman, Wayland, Stanton, Van Sycle, Nolin, and Spofford.

TRANSPORTATION, MARKETS, AND IMPROVEMENTS

The Umatilla area is well provided with railroads and hard-surfaced highways. The main line of the Union Pacific system between Omaha and Portland passes through Pendleton and other towns on the Umatilla River. A branch line from Pendleton to Spokane, Wash., serves Adams, Athena, Weston, Milton, and Freewater. Another branch of this system connects Pilot Rock with the main line at Rieth. The Northern Pacific Railway maintains a branch line from Pasco, Wash., to Pendleton, via Van Sycle, Stanton, Smeltz, and Helix. Another branch of this line at Smeltz extends through Waterman to Athena. United States Highway No. 30 passes through the area and connects Pendleton with Portland and with Boise, Idaho. Other hard-surfaced State highways connect practically all the towns of the county and facilitate marketing both locally and outside the State.

The Columbia River is used as a means of freight transportation, but the shipments in 1937 were not large. Oceangoing ships do not reach Umatilla, but it is the principal point where wheat is loaded for shipment to points on the lower Columbia River. Most of the produce is shipped out of the county by rail. A small fraction of the wheat grown is marketed at local flour mills and in some years part of it is shipped east, but most of it goes to Portland, and from that place much of it has been shipped to Japan, China, and other countries. Cattle are nearly all marketed in Portland, but sheep are shipped to Denver. Chicago, Omaha, Kansas City, St. Louis, and other midwestern markets. Fruits and turkeys are marketed locally and in adjacent States and some are shipped to midwestern and eastern markets.

Schools, churches, telephones, and a supply of good water are available in most parts of the area. Electric power reaches all the important towns and is used in some rural sections for pumping water, lighting, and other purposes. The largest use for pumping irrigation water is in the Walla Walla Valley.

AGRICULTURE

Prior to settlement of this section by the white people, agricultural activities by Indians included only the raising of a small acreage of maize and other edible seeds. It is believed that the Indians of this section obtained horses from Mexico long before the white settlers came, possibly as early as 1750. About 1870, according to early reports, one Indian chief owned a band of about 5,000 horses. In 1841, Marcus Whitman raised 300 bushels of wheat at his mission near Walla Walla. Most of the pioneers who settled in this section in the period 1851–76 were interested in raising cattle, sheep, and horses. Both irrigation farming and dry farming, however, were carried on. In 1862 wheat was grown near Weston, and in 1865 corn was grown in the same locality. According to reports on early farming in Umatilla County, the Hudson's Bay Company raised grain by irrigation at the junction of Pine and Dry Creeks in 1869 or 1870. Oats, barley, and rye were raised prior to 1865. In 1878 grain was hauled to Umatilla and to Wallula, Wash., where it was loaded on boats and shipped to other points. According to an early settler, cattle and sheep were driven from California and the Willamette Valley to this section about 1859. Prior to building the railroad into this area from the east in 1883, cattle and sheep for market were driven to Wyoming, Colorado, and Nebraska. Most of the steers driven to the Corn Belt were 3 to 5 years old. Ranchers who specialized in raising horses bred Indian ponies to saddle or trotting type stallions, and several thousand of the offspring were sold to midwestern cattlemen and to the United States cavalry.

According to reports of early settlers, Umatilla County experienced comparatively rapid and widespread settlement and agricultural development from 1876 to 1900, a period that marked the transition from stock raising to grain growing. The building of the railroad in 1883 stimulated grain growing and enhanced land values. By 1884 much of the area east and northeast of Pendleton was used for grain. About this date and during the few years immediately following, lands in the drier areas west of Pendleton were used for growing grain under summer-fallow methods. Early settlers broadcast the seed and harvested and threshed the grain by hand or by use of horses. In 1871 a header was used near Athena, and in 1878 a binder and a steam-power thresher were used. In 1888 a combine harvester was introduced, but it needed so many improvements that it was not used widely until about 1895. In 1904 and 1905 steam-powered tractors were first used for plowing, and in 1907 to 1909 the caterpillar-type gasoline-powered tractor was introduced. Use of the present Diesel oil-burning caterpillar types was begun in 1932. The acreage planted to wheat increased steadily from the beginning of wheat production until 1930. During World War I and following it, the boom in wheat growing greatly increased the acreage. Many fields that had shallow, sandy, or droughty soils were seeded to wheat but have since been abandoned and are now used for grazing.

During the periods of expansion in grain growing, cattle and sheep were displaced from much of the range they had used and were grazed in districts where the soil was too shallow or sandy or the moisture was too meager for grain growing.

Irrigation of small acreages near farm homes has been practiced since the beginning of settlement. Organization of irrigation districts and construction of irrigation works to supply water for crops on large acreages began about 1900 and continued until about 1919. During this period several thousand acres in the Walla Walla Valley and in the vicinity of Echo, Stanfield, Hermiston, and Umatilla were developed and used for growing fruits, alfalfa, small grains, corn, and melons.

The data in table 3, compiled from Federal census reports, show the acreages of the principal crops grown in Umatilla County.

TABLE 3.—*Acreages of principal crops grown in Umatilla County, Oreg., in stated years*

Crop	1879	1889	1899	1909	1919	1929	1939
	Acres	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
Wheat	31,046	126,827	182,236	186,217	224,611	252,397	191,270
Barley	10,641	8,038	12,857	27,830	14,820	8,139	16,514
Oats (threshed)	3,364	2,946	1,885	1,077	795	578	3,415
Corn (for grain)	336	647	330	384	732	283	1,089
All hay and forage	7,975	26,431	30,693	45,536	60,769	49,526	39,917
Alfalfa	----------	----------	3,934	13,783	20,483	25,349	23,990
Clover or timothy, alone or mixed	----------	----------	----------	2,639	798	556	416
Clover	----------	----------	428	25	288	131	[1] 114
Small grain hay	----------	----------	22,167	28,138	28,889	21,163	13,756
All other tame hay	----------	----------	2,420	----------	182	387	868
Wild hay	----------	----------	1,744	951	1,129	1,940	773
Potatoes	[2] 81,528	729	696	1,160	1,064	1,247	896
Market vegetables	----------	----------	----------	----------	192	519	[3] 18,665
	Trees	*Trees*	*Trees*	*Trees*	*Trees*	*Trees*	*Trees*
Apples	----------	20,915	103,033	55,657	196,176	147,216	43,012
Cherries	----------	469	8,866	8,121	19,093	24,555	30,921
Peaches	----------	5,108	19,064	39,610	25,804	3,407	11,054
Pears	----------	1,482	18,597	5,246	11,361	2,859	10,258
Plums and prunes	----------	4,985	48,408	25,955	110,218	238,501	200,516
	Vines	*Vines*	*Vines*	*Vines*	*Vines*	*Vines*	*Vines*
Grapes	----------	----------	45,713	----------	22,498	10,222	11,281

[1] Sweetclover.
[2] In bushels.
[3] Including 17,749 acres in green peas.

The increases and decreases shown in the table are mainly correlative with increases in population and new developments in machinery and marketing facilities, but some are associated with the relation of production and marketing costs to commodity prices. The 1930 and 1940 data are more accurate than those of earlier years. According to the 1940 records, 1,609,180 acres were in farms in Umatilla County. The value of land and buildings was $37,658,315. Land available for crops in 1939, which includes all land harvested, crop failure, idle, fallow, and plowable pasture, was 648,132 acres. In the same year crops were harvested on 281,143 acres.

Tractors are used for nearly 90 percent of the farm operations necessary to wheat production, and practically all are of the caterpillar type. About 75 percent use Diesel or fuel oil, and the rest gasoline. Nearly all the new tractors purchased are either the Diesel or fuel-oil type. More than 80 percent of the land is tilled with the disk, and the rest is plowed with the moldboard plow. This type of plow is used on the heavier textured soils, which generally are in the higher foothills but below the more heavily timbered areas. Other implements include harrows, drills, blade and rod weeders, binders, mowing machines, trucks, and wagons. Usually a 10- to 20-foot strip is cut around the fields of grain, and used as hay.

Wheat was harvested on 191,279 acres in 1939, and approximately the same acreage of summer fallow was prepared for wheat. The acreage used for the production of wheat was about six times as great as that used for all other crops harvested. It is seeded both in fall and in spring, and several varieties are grown, the choice depending upon type of soil, rainfall or moisture conditions, and temperatures in different parts of the area. Most of the wheat seeded is treated for smut by the 50-percent copper carbonate dry treatment, but a few farmers are using the ethyl phosphate of mercury treatment. The time that wheat ripens is very closely associated with the elevation at which grown. Harvest on the lower lying lands begins about July 1, and on the higher lands it is completed late in August or early in September.

Combines are used almost universally for harvesting wheat. The swath ranges from 12 to 20 feet with 16-foot and 18-foot cuts predominating. More than 95 percent of the harvesters are pulled by tractors, and the rest by horses. About 25 percent of the wheat acreage, or about 10 to 15 percent of the grain, is sacked and the rest is handled in bulk. In districts near Pendleton, Pilot Rock, Adams, Athena, Weston, and Milton, nearly all the grain is handled in bulk, being hauled from the combine in trucks with tight beds and delivered at elevators. In the more outlying districts near Holdman and Echo and several miles southwest of Pendleton, where the distance to elevators is much greater than in other wheat-producing districts, most of the grain is sacked. To increase soil fertility, the use of straw spreaders on combine harvesters is quite general in wheat-growing districts.

In 1939 the plowable pasture of the county was 99,722 acres. All other land, which includes woodland pasture and pasture other than plowable, was 603,124 acres. Most of this acreage is outside the Umatilla area.

Grimm alfalfa, according to the county agricultural agent, yields an average of about 3½ tons an acre. Most of the hay is fed or sold locally and used for feeding cattle or sheep. Between 50 and 100 carloads are shipped annually to the Willamette Valley and other coast points.

The Federal census of 1940 showed 13,756 acres of grain cut for hay in 1939. Much of this is produced in strips around the outer margins of the grain fields and most of it is fed on the farm.

In 1939, 16,514 acres of barley produced 398,844 bushels of grain. Club Mariout and Trebi varieties are grown for grain, and Meloy, a beardless variety, is usually cut for hay. Seeding is early in spring at the rate of 2 bushels an acre, and yields of 25 to 85 bushels are obtained, depending upon the soil, moisture conditions, and farm practices. Seed is treated for smut by use of 1 part of formaldehyde to 40 parts of water. The grain is used principally for stock feed.

Oats for grain were grown in 1939 on 3,415 acres. Markton is the principal variety. Seeding is early in spring at about 2½ bushels an acre, and the yields range from 25 to 90 bushels, depending upon season, locality, and character of soil. The grain is fed locally.

Corn is grown in the irrigated districts, where it is used for fodder, silage, and grain. Yellow Dent is the principal variety. Yields of fodder are 5 to 8 tons an acre, and of grain 25 to 35 bushels. A large part of the grain is fed to turkeys, and the rest is sold and used locally.

The 1940 census showed that 4,096 acres in the county were used for orchards, vineyards, and nut trees.

Federal census data indicate that in Umatilla County in 1939 clover was harvested for seed on 249 acres; alfalfa for seed on 347; grass for seed, 770; sweetclover cut for hay, 114; field peas, 619; field beans, 137; green peas, 17,749; tomatoes, 348; asparagus, 168; squash, 87; watermelons, 67; sweet corn, 52; cantaloups and muskmelons, 46; green beans (snap, string, or wax), 30; carrots, 16; lettuce, 16; cabbage, 14; cucumbers, 11; spinach, 9; and dry onions, 7 acres.

Peas have been grown for seed since 1931 and for commercial canning since 1932. The acreage planted for canning has been increased each year and in 1939 approximated 18,000 acres. The principal early varieties are Alaska and Wisconsin Early Sweet, and the principal later maturing varieties are Perfection and Early Surprise. Other varieties are being tested. Peas were first planted near Weston, and each year the area has been extended higher into the mountains and farther into the lower lying lands. At present the production area extends from the vicinity of Adams to and within the timbered belt in the mountains. Following completion of a cannery at Pendleton, pea growing probably will be extended to many of the foothill slopes southeast and south of Pendleton and east of Pilot Rock, where temperatures are favorable. The pea weevil is the only pest that seriously affects peas at present, the aphids being occasionally injurious to plants during warm, moist seasons. Peas infested with weevils are condemned for canning, but some of the infested plants are allowed to mature for seed. Plowing immediately after the green peas are harvested is practiced in an effort to prevent development and spread of the weevil.

Potatoes are an important crop both in mountain and irrigated districts. Netted Gem (a strain of Russet Burbank) and Irish Cobbler varieties are grown. Much of the crop grown in the mountainous districts is sold for seed, but that grown in the irrigated districts is sold for table use. Yields in the mountains range from 60 to 150 bushels an acre, and under irrigation the yields are generally 125 bushels or more. Early potatoes are dug near Hermiston the last 10 days of June and the first week of July. Late potatoes and those grown in the mountains are dug late in September or in October. Most of them are sold locally.

Apples, cherries, prunes and plums, peaches, and small quantities of pears and apricots are sold fresh and shipped out of the county. Most of the pears, peaches, and apricots produced are sold at local markets. About 29,000 boxes of apples, 5,000 boxes of cherries, and 140 tons of plums and prunes were sold locally in 1935. Considerable quantities of fruit also are used for canning, brining, or drying, for manufacturing vinegar, and for home consumption, and some are not harvested. The principal varieties of apples are Winesap, Delicious, Rome Beauty, and Jonathan. Principal varieties of other fruits are Bartlett pears; Bing, Lambert, and Royal Ann cherries; Italian prunes; and Elberta, J. H. Hale, and clingstone varieties of peaches. Most of the grapes are of the Concord variety.

Commercial fertilizers are used to a limited extent in the fruit-growing districts. The types used are commercially mixed products that are usually bought locally in less-than-carload lots. Organic fertilizers are preferred. Barnyard manure from dairy farms and feeding lots is commonly used.

Table 4, compiled from Federal census reports, gives the number and value of domestic animals and poultry on farms in the county.

TABLE 4.—*Number and value* [1] *of livestock on farms in Umatilla County, Oreg., in stated years*

Livestock	1880 [2]	1890 [2]	1900 [2]	1910 [3]		1920 [4]		1930 [5]		1940	
	Number	Number	Number	Number	Value	Number	Value	Number	Value	Number	Value
Horses	16,402	17,768	16,827	19,051	$1,837,791	18,181	$1,478,600	10,065	$537,490	7,261	$351,786
Mules	257	177	342	2,195	325,865	4,294	636,439	3,400	193,510	413	28,951
Cattle	33,262	22,100	19,571	17,059	460,150	33,217	1,865,141	22,947	1,287,654	29,621	1,298,383
Swine	4,063	8,622	10,027	8,997	70,053	12,505	234,824	3,690	63,233	8,246	71,348
Sheep	267,782	153,719	222,907	242,280	1,006,571	166,649	2 122,876	138,301	1,109,101	125,275	736,816
Chickens	[7] 26,284	84,329	[8] 71,363	[9] 84,090	42,124	115,503	[10] 124,086	115,491	94,703	117,266	58,633

[1] Value not reported for 1880, 1890, and 1900.
[2] Animals of all ages on June 1
[3] Animals of all ages on Apr. 15.
[4] Animals of all ages on Jan 1.
[5] Animals on Apr 1, excluding horses, mules, and cattle under 3 months, swine and chickens under 3 months, and sheep under 6 months
[6] Animals on Apr 1, excluding horses, mules, and cattle under 3 months, swine and chickens under months, and sheep under 6 months.
[7] Chickens exclusive of spring hatching.
[8] Chickens over 3 months.
[9] All poultry over 3 months.
[10] Includes value of 4,039 other poultry.

Beef cattle are permitted to range in certain mountain districts in summer and on the lowland pasture in fall and winter. Some are pastured in fields of wheat stubble or are fed in the alfalfa-producing districts during the fall and winter months. Practically all are marketed in Portland. Hereford is the principal breed raised.

Dairying is important in irrigated districts and in the valleys near towns. Jerseys outnumber the Holstein-Friesians, and about 15 percent of the total number in the county are Guernseys. Most of the dairy products are sold locally, although some butter is shipped.

Sheep raising is more important in this area than raising beef cattle. Although there are a considerable number of pure Rambouillets, most of the sheep are cross breeds, a Lincoln being crossed with a Rambouillet, and the offspring with a Hampshire. Sheep range in national forests of the Blue Mountains in summer and on the foothills or grassy plains in fall and winter. Some range on wheat stubble, and some are fed or pastured in the valley bottoms on native grass pastures or on alfalfa. The lambing season begins about February 15, and late in July or in August lambs weighing 75 to 85 pounds are shipped to eastern markets, mainly to Denver, Chicago, St. Paul, Omaha, and Kansas City.

According to the 1940 Federal census there were 117,266 chickens, 5,265 turkeys, 403 ducks, 8,246 hogs and pigs, 108 goats and kids, and 3,934 hives of bees in the county.

White Leghorn is the leading breed of chickens raised; other important breeds are Plymouth Rock and Rhode Island Red. Most of the turkeys are Bronze, but there are many of the White Holland and Narragansett breeds. Eggs, turkeys, and honey are either shipped or marketed locally. Most of the geese, ducks, hogs, and rabbits are sold at local markets or used for home consumption.

In 1940 the average size of farms in Umatilla County was 696 acres. The area of improved land to the farm is much less; it averaged 280.3 acres in 1939. In the irrigated districts the size ranges from less than 10 to more than 100 acres but averages about 30. The average size of farms in orchards is about 10 acres. In dry-farming districts, the size ranges from 80 acres to several thousand acres. Although the size of farms has increased almost continuously since the settlement of the county began, no material changes appear to be occurring at present.

Farms operated by full owners, according to the Federal census, in 1940, numbered 1,262; by part owners, 495; by managers, 20; and by tenants, 535. In the irrigated districts many are operated by tenants, and most of the farmed land in the Umatilla Indian Reservation is leased to white farmers, on an annual payment of $5 or $6 an acre. In most other parts of the county the owner furnishes only the land and receives one-third of the crop, though his share varies in different districts from a fifth to a half, depending upon yields.

Laborers are practically all American whites. The greatest demand for them is during wheat harvest in July and August and during fruit harvest in August, September, and October.

SOIL SURVEY METHODS AND DEFINITIONS

Soil surveying consists of the examination, classification, and mapping of soils in the field and the recording of their characteristics, particularly in regard to the growth of various crops, grasses, and trees.

The soils and the underlying formations are examined systematically in many locations. Test pits are dug, borings are made, and exposures, as in road or railroad cuts are studied. Each excavation exposes a series of distinct soil layers, or horizons, called collectively the soil profile. Each horizon of the soil, as well as the underlying parent material, is studied in detail, and the color,[4] structure, porosity, consistence, texture, and content of organic matter, roots, gravel, and stone are noted. The reaction of the soil and its content of lime and salts are determined by simple tests.[5] The drainage, both internal and external, and other external features, as relief or lay of the land, are taken into consideration, and the interrelation of the soil and vegetation is studied.

The soils are classified according to their characteristics, both internal and external, special emphasis being given to features that influ-

[4] RICE, T. D., NICKERSON, DOROTHY, O'NEAL, A. M., and THORP, JAMES PRELIMINARY COLOR STANDARDS AND COLOR NAMES FOR SOILS. U. S. Dept. Agr. Misc. Pub. 425. 12 pp., illus 1941.

[5] The reaction of the soil is its degree of acidity or alkalinity expressed mathematically as the pH value. A pH value of 7 indicates precise neutrality; higher values, alkalinity; and lower values, acidity. The total content of readily soluble salts is determined by the use of the electrolytic bridge. Phenolphthalein solution is used to detect a strong alkaline reaction, and dilute hydrochloric acid to detect lime.

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area is covered by a mantle of fine floury wind-borne material called trees. On the basis of these characteristics soils are grouped into classification units, the three principal of which are (1) series, (2) type, and (3) phase; some areas that have no true soil—as riverwash or bare rocky mountainsides—are called (4) miscellaneous land types.

The series is the most important unit, embracing groups of soils having the same genetic horizons, similar in their important characteristics and arrangement in the soil profile, and having similar parent material. Thus, the series comprises soils having essentially the same color, structure, natural drainage conditions, and other important internal characteristics, and the same range in relief. The texture of the upper part of the soil, including that commonly plowed, may vary within a series. The soil series are given geographic names taken from localities near which they were first identified. Palouse, Walla Walla, Ritzville, and Helmer are names of important soil series in the Umatilla area.

Within a soil series are one or more soil types, defined according to the texture of the upper part of the soil. Thus, the class name of this texture, as sand, loamy sand, sandy loam, loam, silt loam, clay loam, silty clay loam, and clay, is added to the series name to give the complete name of the soil type. For example, Walla Walla very fine sandy loam and Walla Walla silt loam are soil types within the Walla Walla series. Except for the texture of the surface soil, these soil types have approximately the same internal and external characteristics. The soil type is the principal unit of mapping, and because of its specific character it is usually the soil unit to which data concerning crops and soil management are definitely related.

A phase of a soil type is a variation within the type, differing from the type in some minor feature, generally external, that may be of special practical significance. Differences in relief, stoniness, and the degree of accelerated erosion may be shown as phases. Practically, some areas within the normal range of relief for a soil type may be adapted to the use of machinery and the growth of cultivated crops and others may not. Even though no important differences may be apparent in the soil itself or in its capability for the growth of native vegetation throughout the range in relief, there may be important differences in respect to the growth of cultivated crops. In such instance the more sloping parts of the soil type may be segregated on the map as a sloping or a hilly phase. Similarly, some soils having differences in stoniness may be mapped as phases even though these differences are not reflected in the character of the soil or in the growth of native plants.

The soil surveyor makes a map of the county or area, showing the location of each of the soil types, phases, complexes, and miscellaneous land types, in relation to roads, houses, streams, lakes, section and township lines, and other local cultural and natural features of the landscape.

SOILS

The soils of the Umatilla area have a wide range in characteristics and in suitability for crop production. They owe their diversity not only to differences in character of the parent soil materials, but probably still more to the range in rainfall, temperature, and vegetation under which they have developed. By far the greater part of the area is covered by a mantle of fine floury wind-borne material called loess; although considerable areas of the Columbia River terraces in the northwestern part consist of coarse sandy and gravelly deposits, with adjacent areas of coarse sandy wind-drifted materials; variable gravelly and finer alluvial and lake-laid deposits lie in the valleys of the Walla Walla River, the Umatilla River, and smaller tributary streams; and in places, especially on stony mountain slopes and canyon sides the soil material has been formed largely through disintegration and decomposition of the underlying basaltic bedrock.

The depth and the texture of the mantle of soil material have had and still have a profound effect on soil moisture conditions and, together with differences in rainfall and temperature, have determined the character of vegetation and the consequent soil development and now affect the productivity of the soil and its suitability for crop growing. On the light-colored soils in the dry northwestern part, sagebrush and other desert shrubs have been the chief vegetation and have contributed little organic matter (humus) to the soils, and leaching has not removed lime or other bases to great depths. At intermediate elevations on the plains to the southeast, bunchgrasses have contributed somewhat more organic matter and a darker color, and lime has been leached to a somewhat greater depth. Nearer the mountains the rainfall has been greater, the growth of grasses is more luxuriant, and the soils are darker colored, richer in organic matter, and more deeply leached. The darkest colored soils with the highest content of organic matter are along and in the foothills of the Blue Mountains. In the higher elevations of the mountains, where the rainfall is greater and evaporation less, forests of pine, fir, spruce, and tamarack flourish. In the lower parts of the timbered belt open stands of western yellow pine with undergrowth of grasses and small shrubs have led to the development of soils of intermediate color and organic content, whereas in the somewhat higher, more moist, and cooler belt the dense stands of fir, spruce, ad tamarack have led to the formation of acid, leached, and light-colored soils of low organic content.

Over the greater part of the area, the supply of soil moisture available to plants is the most important factor in determining what crops may be grown and what the yields will be. In a comparatively small part, the natural supply is supplemented by irrigation, but by far the greater part depends upon the precipitation—rain and snow—which in most parts is not sufficient in quantity and not well enough distributed to produce the highest yields of crops. The northwestern part is too dry for successful crop production without irrigation. Much of the central wheat belt receives only enough moisture to produce wheat under a system of dry farming that includes summer fallowing and uses the moisture of two seasons to produce a single crop.

Along the foothills of the Blue Mountains sufficient moisture is received to allow the growing of peas in alternate years, in place of summer fallow. Farther up in the mountains sufficient moisture is available for crops to be grown every year and for corn and potatoes to be raised in addition to wheat and peas. Finally, at the highest elevations, red clover, timothy, potatoes, small grains, and berries are grown, but because of low soil fertility and dry summers they are not highly productive. In this highest belt there is a good stand

and vigorous growth of forest cover, and it may be considered doubtful whether the land is sufficiently productive of farm crops to warrant its being cleared.

In the lower parts of the area, the soils are mostly well drained or excessively drained under natural conditions; but in places seepage has developed, largely since the land was put under irrigation. In such places salts have accumulated to such an extent as to prevent the growing of most crops. Most of such areas support grasses that furnish some pasture.

For convenience in discussion and to bring out significant soil characteristics and relations in the report and on the accompanying map, the soils of the area have been grouped in the general order of agricultural importance, the most extensive and agriculturally important group first, as follows: (1) Medium- to dark-colored soils of the smooth to rolling loessal plains, which make up the central and greater part of the large wheat-producing belt and include minor areas where peas are grown; (2) light-colored soils of the smooth to rolling plains and lake terraces, which are extensive in the western and northern parts and include a large acreage of dry-farmed wheatland, smaller areas of good irrigated land, and considerable areas of livestock range; (3) dark-colored soils of the foothills and lower mountains, which are used for wheat, peas, potatoes, and corn; (4) light-colored soils of the Blue Mountains, which are largely under a dense forest cover but contain small cleared areas that produce medium to low yields of hay and potatoes and fairly good yields of berries; (5) light-colored sandy soils of the Columbia River terraces, which are too sandy and droughty for dry farming, in part too sandy for irrigation, but in part under irrigation and fairly productive of alfalfa, corn, small grains, potatoes, melons, vegetables, and tree fruits; (6) soils of the bottom lands and low terraces, which have a wide range in characteristics, but include much good irrigated land, producing alfalfa, apples, prunes, potatoes, corn, small grains, and vegetables, with some areas dry farmed or in pasture; and (7) miscellaneous nonarable soils and land types that furnish grazing, and in the mountains, some timber.

In the following pages the soils of the Umatilla area are described in detail and their agricultural importance is discussed; their location and distribution are shown on the accompanying soil map, and their acreage and proportionate extent are given in table 5.

MEDIUM- TO DARK-COLORED SOILS OF THE SMOOTH TO ROLLING LOESSAL PLAINS

The medium- to dark-colored soils of the smooth to rolling loessal plains are the most extensive group in the Umatilla area. They occupy a belt of plains, ranging from about 6 to 25 miles wide, parallel to the foot of the Blue Mountains, and extending into the foothills in places. They range from grayish brown to dark grayish brown or almost black and have slightly to distinctly granular surface soils that are dominantly silt loam but range from very fine sandy loam to silty clay loam. In most places they have a concentration of lime in the lower subsoil layer. These soils vary greatly in depth, in character of substratum, and in productivity.

This group includes the Athena, Walla Walla, Pilot Rock, Morrow, and McKay soils. The Athena soils are the darkest in color and most highly productive. The Walla Walla soils are somewhat lighter and somewhat less productive but much more extensive, and, in fact, produce a large part of all the wheat grown in the area. The Pilot Rock soils are shallow soils over lime hardpan that caps beds of gravel or basalt bedrock and are lighter colored than the other soils of the group and less productive than most of them. The Morrow soils are very shallow soils over bedrock; typically, they have heavy subsoils that contain no lime and are comparatively low in productivity. The McKay soils are dark-colored and have a claypan subsoil overlying beds of gravel, more or less cemented by lime, and are similar in productivity to the Walla Walla soils.

TABLE 5.—*Acreage and proportionate extent of the soils mapped in Umatilla area, Oreg.*

Soil type	Acres	Percent	Soil type	Acres	Percent
Athena silt loam	29,568	2 5	Ephrata loamy sand	19,008	1.6
Walla Walla silt loam	109,376	9 1	Poorly drained phase	2,688	2
Light-textured phase	124,480	10.4	Ephrata sand	42,688	3.6
Shallow phase	3,328	.3	Shallow phase	6,656	.6
Walla Walla very fine sandy loam	16,704	1 4	Rupert coarse sand	13,952	1 2
Pilot Rock silt loam	68,992	5 7	Rupert sand	10,304	9
Deep phase	6,976	.6	Winchester sand	14,912	1.2
Morrow silt loam	19,200	1 6	Snow silt loam	4,736	.4
Morrow silty clay loam	20,224	1 7	Caldwell silt loam	2,688	.2
McKay silt loam	11,648	1 0	Saline phase	5,120	.4
Ritzville silt loam	34,816	2 9	Caldwell silty clay loam, saline phase	896	.1
Shallow phase	27,008	2 3	Hermiston silt loam	7,168	.6
Ritzville very fine sandy loam	87,808	7 3	Hermiston very fine sandy loam	11,456	1 0
Shallow phase	14,144	1 2	Onyx loam	8,704	7
Ritzville fine sandy loam	4,800	4	Onyx fine sandy loam	4,672	.4
Ritzville loamy fine sand	13,312	1 1	Onyx loamy fine sand	1,856	.2
Sagemoor silt loam	3,904	3	Yakima cobbly loam	6,464	.5
Burke silt loam, saline phase	1,792	.1	Yakima gravelly loam	4,800	.4
Palouse silt loam	10,176	8	Yakima loam	1,280	.1
Steep phase	960	.1	Yakima silt loam	832	.1
Waha silty clay loam	28,288	2 4	Stanfield very fine sandy loam	5,824	.5
Deep phase	6,400	.5	Stanfield fine sand	512	(1)
Waha silt loam	5,120	.4	Umapine very fine sandy loam	1,728	.1
Deep phase	832	.1	Waha stony silt loam	6,720	6
Thatuna silty clay loam	4,288	.4	Underwood stony loam	3,648	.3
Poorly drained phase	576	(1)	Scabland	9,152	8
Helmer silt loam	18,624	1 5	Shallow stony soils	50,368	4.2
Couse silt loam	5,632	.5	Rough broken and stony land	213,056	17.8
Quincy loamy fine sand	16,576	1 4	Timbered phase	13,184	1.1
Wind-eroded phase	1,792	.1	Riverwash	8,064	.7
Shallow phase	1,472	.1	Volcanic ash	384	(1)
Quincy fine sand	11,008	.9			
Hummocky phase	1,344	.1			
Ephrata fine sandy loam	3,392	.3	Total	1,198,080	100.0

[1] Less than 0.1 percent.

The soils of the group have developed mostly from fine floury wind-borne material (loess), although the shallow Walla Walla, Morrow, and many areas of the Pilot Rock soils lie over basalt bedrock at a shallow depth, and the McKay soils and other areas of the Pilot Rock soils lie over beds of water-rounded gravel. It seems probable that the heavy subsoil materials of the Morrow soils consist largely of residue from the decay of the underlying basaltic bedrock.

The soils of this group are used mostly for the production of wheat under dry-farming methods, although peas are grown to some extent on the Athena soils.

Athena silt loam.—This soil occupies an irregular but extensive belt in the higher part of the plain and in the lower foothills, from the Umatilla River at a point north of Cayuse northeastward to the Oregon-Washington State line. It occupies 46.2 square miles. The surface commonly ranges from undulating to rolling and in small areas is rather steep.

The soil is well drained but excessive runoff on the steeper areas causes accelerated erosion where the surface is not protected by vegetation. It is a deep, dark-colored, fine-textured soil, granular, permeable, easily worked, fertile, and highly productive under dry farming (pl. 2, *A*). The native vegetation consists largely of bunch-grasses, but the land is nearly all under cultivation.

A representative profile of this soil, taken from the gently sloping upland plain east of Athena, is as follows:

0 to 16 inches, dark brownish-gray granular friable noncalcareous[6] silt loam, appearing nearly black when moist; relatively high in organic matter.
16 to 30 inches, medium-brown friable noncalcareous heavy silt loam, with indistinct coarse prismatic structure.
30 to 54 inches, light-brown mellow noncalcareous silt loam with indistinct coarse prismatic structure.
54 to 70 inches, pale-brown or yellowish-brown slightly calcareous mellow silt loam; contains a few soft concretions of color similar to that of the looser soil material.
70 to 110 inches, light grayish-brown noncalcareous silt loam, firm but easily crumbled; contains many fine pores or root channels and many roots, although not so many roots as the layers above.
110 to 126 inches, light grayish-brown calcareous silt loam, firm but friable.
126 to 144 inches, light yellowish-brown, firm but friable silt loam.

Considerable variation exists in the thickness of the soil layers and in the depth to the layer of lime concentration. The surface soil is generally somewhat thicker and slightly darker on the slopes facing the north and east than on those facing the south and west. The layer of accumulated lime lies at depths of 4 to 6 feet or more below the surface.

Practically all this soil is cultivated, largely for dry-farmed wheat. Summer fallowing is practiced on much of the land, although in recent years peas have been grown on considerable acreage in the alternate years between wheat crops. Wheat yields 35 to 60 bushels an acre, averaging about 40 bushels following peas and about 45 bushels following summer fallow. Peas grown for canning yield 2,000 to 3,000 pounds or more an acre.

The continuous practice of alternating summer fallow and wheat has the effect of gradually depleting the organic matter and fertility of the soil, especially where the wheat stubble is burned. On the steeper areas the depletion of organic matter probably tends to accelerate erosion. It is somewhat difficult to plow under the heavy wheat stubble, and when the land is plowed too late in spring the straw decays slowly and may lower the yield of the next season's wheat crop. If the stubble land is plowed early enough, however, leaving the surface rough and cloddy, comparatively little difficulty will be experienced either from lack of decomposition of straw or from soil erosion. Some of the steepest areas should be kept in grass or, if cultivated, should be left bare as little as possible. Crested wheatgrass appears to be well adapted to this soil.

Walla Walla silt loam.—This is one of the most extensive and important soils in the area. It covers an area of 170.9 square miles, forming a belt several miles wide extending northeastward from the Umatilla River to a point on the Oregon-Washington line northeast of Spofford. Its high undulating and rolling plains lie to the east of and somewhat higher than a belt occupied by the light-textured phase of

[6] See footnote 5, page 15.

Walla Walla silt loam and west of and slightly lower than that of the Athena silt loam. The elevation ranges from about 1,400 to 2,000 feet above sea level. The average annual rainfall ranges from about 15 to 18 inches.

The land is generally fairly smooth to gently rolling and consists largely of a series of parallel gently sloping ridges which, in some places, have smooth uniform slopes and in others are cut by lateral drainageways and are very rolling. Slopes to the north and east are generally long and gentle and those to the south and west are shorter and steeper. The ridges range from ¼ to 1½ miles wide, averaging about 1 mile. The valleys separating them are usually V-shaped and are cut from only a few feet to as much as 100 feet or more below the general level of the ridge tops. Both external and internal drainage are good.

The 8-inch surface soil of Walla Walla silt loam is medium to dark brownish-gray mellow floury or fine granular silt loam. When moist it is brownish black. It contains a fair supply of organic matter and no lime and is slightly acid or neutral. Beneath is material similar in texture to the surface soil but a shade lighter in color and of a rather indistinct coarse prismatic structure. The prisms are very soft and can be crushed with slight pressure to small clods or to a powder. They are 2 to 4 inches in diameter and have fairly distinct outlines in the upper parts, but at an average depth of 15 inches below the surface layer they become somewhat less distinct as the material merges with weak or pale-brown mellow noncalcareous silt loam. As the depth increases there is a decrease in the number of dark stains from organic residues, and at 24 to 36 inches the soil material is a shade lighter in color and even more friable than that above. Between 36 and 60 inches is pale-brown noncalcareous soft floury silt loam, underlain by very pale-brown or light brownish-gray mildly calcareous friable silt loam. A few irregular-shaped lime carbonate nodules 1 to 3 millimeters in diameter occur in this layer. At a depth of about 68 inches and continuing to the underlying bedrock the material is very light brownish gray or very pale-brown highly calcareous friable light silt loam or loam that contains a few soft lime carbonate nodules.

To a depth of about 16 inches Walla Walla silt loam is slightly acid or neutral and below that depth it is alkaline. The soil has very desirable structure, texture, consistence, and water-holding capacity, is easy to cultivate, and exceptionally well adapted to growing wheat under dry-farming methods (pl. 3, *A*). Plant roots are numerous in the dark-colored upper layer, and fine grass roots penetrate more than 8 feet below the surface. In a large part of this type the bedrock is covered by more than 6 feet of soil material, although in a few places the rock lies at depths of between 3 and 6 feet. The soil generally is somewhat deeper and darker colored on the north and east slopes than on those with southern and western exposure. This condition is the result of a number of factors, including greater deposition of loess on leeward (northeastern) slopes, less exposure to sun and wind than on the south and west, and consequently more vigorous vegetation and less rapid erosion.

This soil has developed from fine-textured wind-laid material (loess), and the native vegetation responsible for its dark color and exceptional fertility consists principally of bunchgrasses.

Practically all this soil is cultivated, and wheat is by far the most important crop. Barley is raised on about 2,000 acres, and a few hundred acres are planted to crested wheatgrass. The usual methods of summer fallow are practiced. Slightly less power is required for plowing and cultivating than on the Waha, Palouse, and Athena soils.

Wheat yields range from about 30 to more than 50 bushels an acre. Average yields in the upper part of the belt, as around Athena, are between 40 and 45 bushels, whereas along the drier western margin of the belt the yield is about 35 bushels. Yields vary, depending on quantity and distribution of rainfall, depth of soil, thickness of the dark-colored surface soil, and degree and direction of slope. Larger yields are obtained on slopes facing the north and east than on those facing the south and west. This is due to a combination of more favorable conditions on the north and east slopes, including deeper soil, higher content of organic matter, gentler slope, better soil moisture conditions, and less exposure to sun and wind.

Barley yields 50 to 80 bushels an acre on this soil and crested wheatgrass about 500 pounds of seed.

Soil erosion does not appear to be serious, but some care is needed to control it in a few places, especially on the steeper slopes. The powdery mulch formed by summer fallowing resists wetting, and sudden hard rains may cause rapid runoff and formation of rills and shallow gullies. This trouble can be partly averted by turning under rather than burning the stubble and straw.

In sections of greater rainfall, the soil is slightly more granular, contains somewhat more silt and clay and less very fine sand, is slightly darker, and the dark-colored surface soil is deeper than average. The opposite conditions exist near its western limits in sections of lower elevation, where the typical soil merges with but is differentiated from the light-textured phase.

Walla Walla silt loam, light-textured phase.—This is the most extensive arable soil in the area, and it produces a large part of the wheat grown there. Its total of 194.5 square miles is in the plains, where it forms several large unbroken and remarkably uniform areas at elevations of 1,200 to 1,800 feet above sea level. The range in rainfall is from about 12 to 15 inches. The surface is smooth to rolling and in most places the general aspect is one of many generally parallel smooth-topped ridges that range in width from a few hundred feet to as much as 2 miles. The slope of the axes of the ridges ranges from less than 1 percent to as much as 10 percent, and the side slopes range from less than 5 to about 20 percent. The north and east slopes are commonly longer and gentler than those facing south and west.

The surface soil, which varies in thickness but averages about 8 inches, is medium to light brownish-gray noncalcareous silt loam that when moist is dark brownish gray or dusky brown. It is soft and mellow and breaks readily to a floury condition. This light-textured phase is similar to the typical soil, but is a shade lighter in color, slightly lighter in texture, and softer in consistence. It contains nearly as much silt as the typical soil but less clay and more very fine sand.

The surface soil is underlain by a layer that averages about 8 inches in thickness and is slightly lighter brownish-gray soft noncalcareous silt loam. In a cut bank where exposure allows the soil to dry and shrink, this layer has a prismatic structure. The prisms, usually 2 to 4 inches in diameter, may be easily broken in the hand to small soft clods, or to a powder. Beneath this and extending to a depth of about 60 inches is pale-brown or light yellowish-brown noncalcareous silt loam, which forms fragile prisms 4 to 6 inches in diameter that crumble readily to a powder. The content of humus stains and organic matter is successively less in each of the three upper layers, the first two of which are very slightly acid, the third slightly alkaline. Below a depth of 60 inches is a very pale-brown or very light brownish-gray softly cemented silt loam. This material contains carbonate of lime, part of which has accumulated in grayish streaks or veins and part is distributed through the soil as nodules and in finer form. Though slightly cemented, the material can be cut by a moderate blow with a shovel and can be crumbled in the hand. This is underlain at an average depth of about 9 feet by parent material of almost unmodified loess, which is less cemented, probably contains less lime carbonate, and is slightly more friable than the layer above.

The soil and subsoil are friable and permeable. The surface soil contains moderate quantities of organic matter but much less than the Palouse and Athena soils and somewhat less than the typical Walla Walla silt loam. It does not extend downward nearly so deep as does the dark-colored surface soil of the Palouse series. Percolation, water-holding capacity, and aeration conditions are very favorable for plant growth, and owing to the soft permeable condition roots are well distributed. They are numerous in the dark material of the upper layers, and small roots, which become less numerous with depth, penetrate more than 10 feet below the surface.

This soil grades almost imperceptibly into the typical Walla Walla silt loam on the east and into Walla Walla very fine sandy loam and the Ritzville soils on the west. Where it borders the Walla Walla silt loam on the east it is slightly darker, contains slightly more organic matter, and the dark-colored surface soil extends deeper than average. Owing to the slightly more fertile condition and to slightly greater rainfall, the soil in these areas is somewhat more productive. Near its western limits where it merges with the Ritzville soils, the color is somewhat lighter and does not continue downward to the average depth. In such places crop yields are below average for this soil. In the vicinity of and between Myrick, Helix, Stanton, and Holdman, depth to basalt bedrock is more than 20 feet in many places and averages more than 8 feet. Extending southward from that district, the average depth of the soil is much less, although it is usually more than 6 feet to bedrock. In the areas southeast of Pendleton the substratum, instead of the usual basalt bedrock, consists in many places of well-rounded stream-deposited gravels that are rather firmly cemented by carbonate of lime. This substratum is similar to that underlying Pilot Rock silt loam. Depth to the cemented gravelly material is usually between 4 and 6 feet below the surface soil. Included with this phase are many small areas in which the soil material consists largely of light-gray, almost white, volcanic ash.

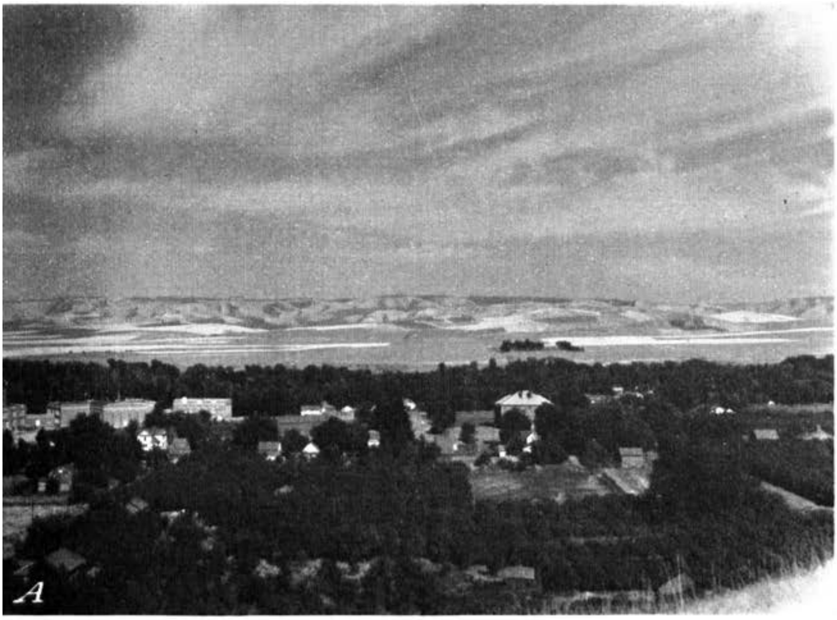
Like most of the other soils of the uplands, this soil is somewhat deeper, somewhat darker colored, and somewhat richer in organic matter on the north and east slopes than on those facing the south and west. The south and west slopes are generally steeper and are more subject to rapid runoff, erosion, and drying out by exposure to sun and wind.

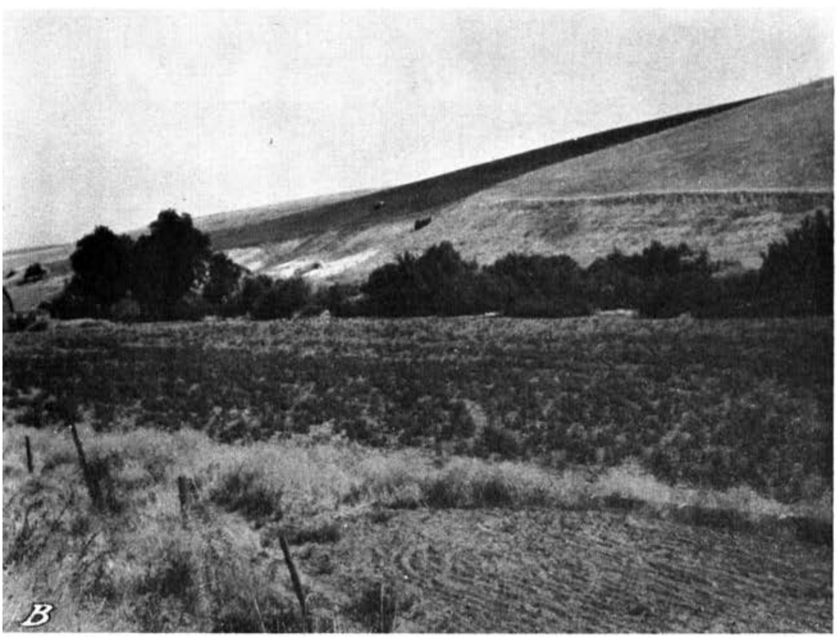
This soil appears to have developed chiefly from fine-textured wind-laid material, apparently blown largely from the Columbia River terraces and probably consisting of a wide variety of rock materials, although much of it may be from basalt and volcanic ash. External and internal drainage are good. Bunchgrass, the principal native vegetal cover, is largely responsible for the dark color of the surface soil.

Practically all this soil is used for growing wheat. Barley is produced on a few thousand acres, and pastures occupy only a few hundred acres. Crested wheatgrass is grown as a seed crop on several hundred acres. The soil is well adapted to the production of grains, and under the universal practice of summer fallow, good yields are obtained. Wheat yields 20 to 40 bushels an acre, averaging about 30. The lower yields are obtained near the western limits, the higher yields from the most easterly parts. Barley yields average about 40 bushels an acre. Grain cut for hay yields about 2 tons. Under the usual system of wheat after summer fallow, which is practiced throughout the entire area, the soil is subjected to and affected by both wind and water erosion. Slight sheet erosion occurs and incipient gullies often develop on the steeper slopes during periods of heavy runoff in spring. Erosion by wind is not very serious, but during periods in spring when comparatively high-velocity winds are frequent there is some shifting of dry surface soil.

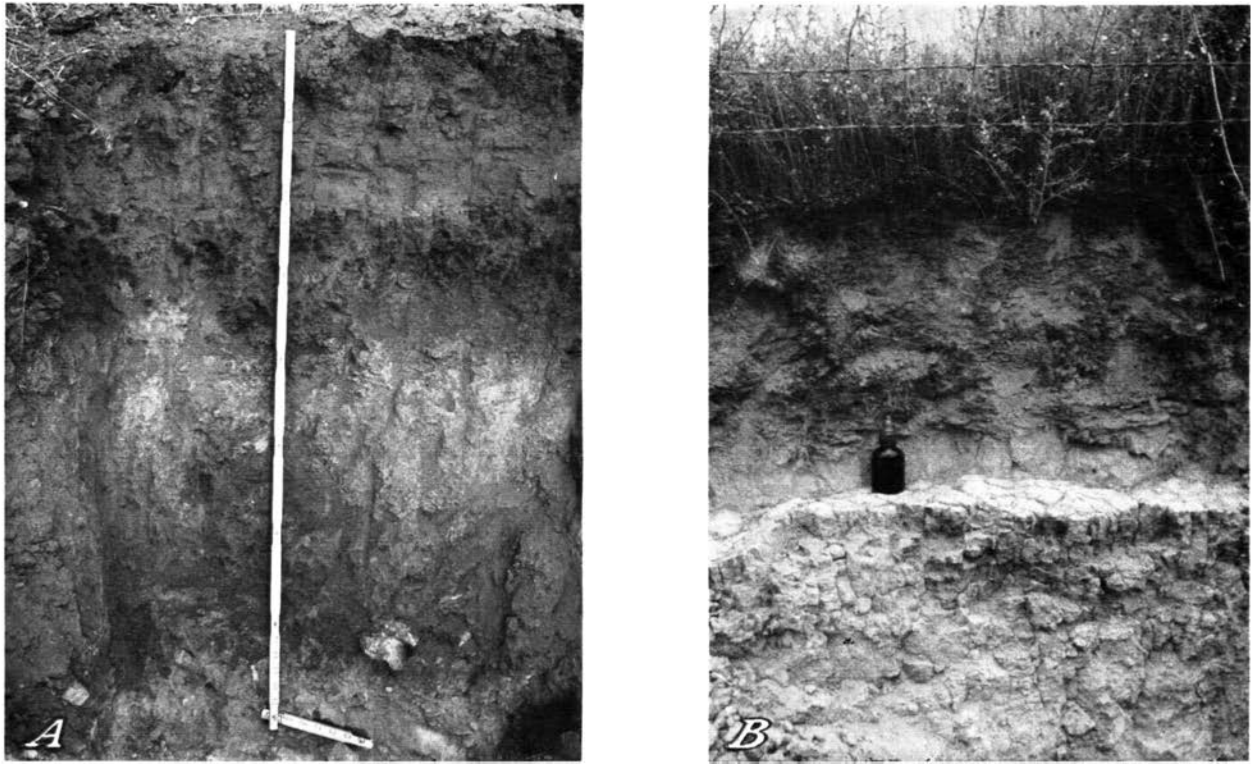
Walla Walla silt loam, shallow phase.—This shallow phase is most extensive in an area about 12 miles southwest of Pendleton, but occurs also in a number of small bodies between Pendleton and the Oregon-Washington line, associated with the typical soil. The total area is 5.2 square miles.

This soil occupies smooth rolling ridges that range from about ¼ to 1 mile wide. Slopes of the axes of the ridges range from 2 to 6 percent and side slopes from about 6 to 12 percent. The elevations of the most extensive areas southwest of Pendleton are 1,700 to 2,800 feet or more above sea level. No official rainfall records are available for that section, but judging from soil characteristics and elevation the rainfall is probably more than 14 inches. In several small areas east of Pendleton, this phase is similar in color, texture, structure, and reaction to the typical soil, but depth to solid basalt bedrock is less than 3 feet. In areas southwest of Pendleton the surface soil is also similar to the typical, but the subsoil is slightly more compact and the texture is somewhat heavier. The 6-inch surface layer, which is weak-brown when dry and dark brown when moist, is friable and granular noncalcareous silt loam. Below this and continuing to a depth of about 15 inches, the material is of similar structure, texture, and reaction but somewhat lower in organic matter and slightly lighter in color. Underlying this is brown firm but friable noncalcareous silt loam or silty clay loam of prismatic structure. The prisms range in diameter from 2 to 4 inches and continue downward to about 22 inches, where they merge with material of similar or slightly lighter brown color without definite structure. This material continues to bedrock, which lies at depths of 2 or 3 feet below the surface. In some places there is very little or no lime carbonate, but usually small quantities occur in





A, Looking eastward across the southern part of the Walla Walla Valley at Milton, in which the soils are of the Yakima series. Walla Walla silt loam on the terrace in the middle ground is used for dry-farmed wheat. Palouse and Waha soils occupy the mountain slopes. *B*, View near Blue Mountain station, the small stream valley in the foreground occupied by Weston soils, and the slope in the background by Palouse silt loam.



A, Profile of McKay silt loam, showing granular surface soil, thin platy subsurface layer, dark-colored prismatic claypan, light-colored limy subsoil, and underlying lime hardpan with embedded gravel. *B*, Profile of McKay silt loam, showing biscuitlike tops of Solonetz columns and uneven surface of the columnar layer.

the layer below a depth of 22 inches, where it is present in very finely divided form and evenly distributed throughout the soil mass.

The parent material consists mainly of wind-laid deposits, and the vegetal cover under which the soil developed was principally bunch-grasses. Where the soil is well covered by grasses there is little erosion, but if this natural cover is destroyed gully erosion, especially on the steeper slopes, often occurs during periods of heavy runoff. Internal and external drainage are adequate.

Practically all this soil is cultivated for wheat. A few areas, each less than 10 acres in size, have been planted to crested wheatgrass, and a few steep slopes are used only for grazing. This soil is easy to cultivate, has moderate or fairly large quantities of organic matter, has fair to good water-holding capacity, and is naturally well adapted to growing wheat or grasses. Its shallowness, however, limits the supply of plant nutrients and the quantity of water that can be stored for use by plants. Wheat yields vary with depth of soil over bedrock and range from 10 to 25 bushels, with an average of about 18 bushels on areas southwest of Pendleton. In bodies located closer to the mountains, where rainfall is greater, the yields average about 25 bushels. Crested wheatgrass yields 170 to 300 pounds of seed an acre, depending on depth of soil and seasonal weather conditions.

Walla Walla very fine sandy loam.—Occupying a belt of rolling uplands this soil occurs at elevations of 1,100 to 1,850 feet above sea level in the vicinity of Holdman and north and south of that place, and on a few small areas near Stanton and between Weston and Milton. The total area mapped is 26.1 square miles.

The soil occupies a series of ridges that range from less than one-fourth mile wide to more than one-half mile. The axes of the ridges generally slope about 3 percent, and the side slopes in many places are as much as 5 percent.

This soil has developed from very fine wind-laid material under a cover of grasses and annual rainfall of about 13 inches. Internal and external drainage are good. Under summer fallow conditions some erosion in the form of incipient gullies often occurs during periods of excessive runoff from unusually heavy rain or melting snow.

The upper 8-inch layer is brownish-gray to light brownish-gray friable noncalcareous smooth very fine sandy loam. Beneath this and continuing to an average depth of 21 inches is pale-brown or light brownish-gray noncalcareous very fine sandy loam that breaks into soft clods of prismatic shape. The prisms are 2 to 4 inches thick and are easily crumbled to powdery or floury mass. Between 21 and 36 inches below the surface the prismatic structure is not apparent, but the soil is light yellowish-brown to light brownish-gray noncalcareous friable very fine sandy loam. Below 36 inches and to a depth of 40 to 50 inches or more is a layer of very pale-brown or very light brownish-gray mildly calcareous friable very fine sandy loam. The depth to lime carbonate is variable from place to place. Below this is a very pale-brown or a very light brownish-gray friable highly calcareous very fine sandy loam. The texture of this latter layer is slightly lighter than that of the upper layers. Distributed throughout this layer are a few small concretionlike lumps of soil that do not effervesce with dilute acid. The carbonate of lime, which is very finely divided, is well distributed throughout these two lower layers and is responsible for the grayish cast.

From the surface downward the various layers become successively slightly lighter in color, owing to the moderate quantity of organic residues in the upper layer and the gradually diminishing quantity in each deeper layer and to the accumulation of lime carbonate in the lower layers. The soil is very friable, easily tilled, and does not form hard clods or bake when drying. It has medium to high water-holding capacity. The soil material of the entire profile is sufficiently friable to permit penetration by roots and water and to allow ideal conditions for bacterial activity, aeration, and oxidation. The surface layer is neutral, the lower ones slightly or moderately alkaline.

Practically all this soil is cultivated. Wheat, the principal crop, yields 20 to 25 bushels an acre, depending upon season and rainfall. The soil is not exceptionally high in its content of nitrates, but in years of much rainfall yields as high as 45 bushels an acre have been harvested.

Pilot Rock silt loam.—This soil occurs on undulating or gently sloping high terraces in the vicinity and to the north of Pilot Rock, and on undulating to gently rolling basaltic uplands to the northwest. The total area mapped is 107.8 square miles. It is a shallow soil very similar to the shallow phase of Walla Walla silt loam, but is somewhat lighter in color and is underlain by firmly cemented lime hardpan. The hardpan overlies beds of lime-cemented gravel on the terraces (pl. 2, *B*), but basaltic bedrock on the uplands. The parent material is a rather thin mantle of fine floury loess overlying the lime-cemented hardpan. The content of organic matter is medium to low. The soil is well drained and, because of its shallowness, has a rather low water-holding capacity. The hardpan is slowly pervious to water but is probably penetrated by few plant roots.

The 7-inch surface layer is light brownish-gray to pale-brown very friable and floury noncalcareous silt loam. Beneath this and continuing to an average depth of about 20 inches is a light brownish-gray friable mildly or moderately calcareous silt loam or loam. This is underlain by very pale-brown or light brownish-gray highly calcareous silt loam that contains a few soft nodules, which range from infinitesimal size to as much a 2 millimeters in diameter. At a depth of 1½ to 3 feet this layer is abruptly underlain by very pale-brown to gray or white firmly cemented hardpan. On the terraces near Pilot Rock the hardpan is underlain by beds of more or less cemented gravel, which is predominantly basalt and well rounded and coated with accumulated lime carbonate. The uppermost 12- or 18-inch gravel layer generally is firmly cemented by lime carbonate. Below that depth, the material is softly cemented and commonly can be dislodged when struck with a shovel. The gravel material generally continues to depths of 6 feet or more but in some places solid basalt bedrock occurs at variable depths between 4 to 6 feet below the surface. On the uplands northwest of Pilot Rock no gravel occurs in either soil or substratum and the hardpan caps basalt bedrock.

Included with Pilot Rock silt loam are several bodies in which the depth of the soil over the hardpan is shallower than average and gravel or gravel and stone are distributed on the surface and throughout the soil. These gravelly or gravelly and stony bodies usually occupy sidehills and slopes where the gravelly material has been exposed in places and has become mixed with the soil material. In many such areas the surface soil is very thin or entirely lacking and limy subsoil is exposed. On the uplands basalt bedrock is exposed in spots.

Most of the soil is cultivated, although a few hundred acres, mostly on the steeper slopes, are used only for grazing. Winter wheat yields 8 to 20 bushels an acre, depending upon the rainfall and its distribution and the depth of soil over gravel or hardpan. This soil is so generally shallow that its capacity for water storage is limited, and rainfall is usually less than 14 inches. These conditions are not favorable to the production of large yields. The comparatively dry condition of both air and soil are favorable for the production of the Mosida and Oro varieties of wheat, which are more resistant to drought and develop higher contents of protein than other varieties grown in the county. Although many of the spots of very shallow gravelly soils are cultivated, the yields average less than 10 bushels an acre. During years when wheat prices are comparatively low, such areas probably would be of greater value if planted to crested wheatgrass.

The carrying capacity of pasture land varies with conditions of the stand as affected by kind of grass, density of stand, the rainfall, number of livestock that have been pastured, depth of soil, and degree of erosion. In overgrazed areas, or in areas where the land has been cultivated and later abandoned, downy bromegrass, together with rabbitbrush, sagebrush, Russian-thistle, and other weeds, forms the principal cover.

On areas where the native bunchgrasses thrive and have not been overgrazed, the carrying capacity is much more than where these are replaced by downy bromegrass, locally called cheat. During 1937 and in the few years preceding, the price per acre paid for pasture in some downy bromegrass areas west and northwest of Pilot Rock was 10 cents, and for lands with abundant bunchgrass in similar located districts, 35 cents. Sheep are grazed ordinarily from March 1 to May 1 and again from November 1 to about December 25. During years when rainfall is abundant late in spring, sheep are grazed on the downy bromegrass areas until May 15 or later. During spring months, downy bromegrass, tarweed, mustard, sunflower, alfileria, and other less conspicuous weeds and plants are eaten by sheep. In the sections west and northwest of Pilot Rock where the grass cover is similar to that of many other areas, 2½ acres will provide feed for one sheep during April, May, November, and most of December. Downy bromegrass probably is not very nutritious in fall, but during that season the available bunchgrass provides a valuable and highly nutritious feed. Some grain or hay is usually fed during fall months and also during January and February.

Pilot Rock silt loam, deep phase.—This soil occurs southeast of Pendleton, and includes 10.9 square miles. It occupies old alluvial terraces at elevations between 1,400 and 1,800 feet above sea level, where it adjoins or is within a few miles of the foothills of the Blue Mountains. The surface soil is slightly darker at the higher elevations near the mountains and southwest of Mission. The land is smoothly sloping, and the gradient averages about 4 percent, or 200 feet to the mile. A few draws or intermittent drainageways that range in width and depth from a few to as much as 15 feet are present, but are not steep-sided or rough, and are usually cultivated with other parts of a field.

The gravelly substrata were deposited probably during glacial periods, when runoff from the high mountains south of the area was unusually high. Most of the surface material appears to be loess. Bunchgrasses have formed the principal cover, and their residues, under the prevailing climatic conditions and the other factors influencing the processes of soil development, have led to the incorporation of organic matter and the consequent darkening of the surface layer.

To a depth of about 10 inches this phase is brownish-gray to light brownish-gray granular noncalcareous silt loam, and when moist it is dark brown to dusky brown. This layer is moderately high in organic matter, and is appreciably darker than the surface layer of the typical soil. Below and to a depth of 17 inches the soil is of similar texture, but contains less organic matter, and is pale brown to light brownish-gray. It appears massive, but not compact, and contains many root channels the size of a pin point, and may be crushed with slight pressure to a floury condition. This material is underlain by a slightly firmer light brownish-gray friable silty clay loam. At an average depth of 24 inches, this layer grades into very pale-brown silty clay loam in which many gray or white accumulations of lime carbonate appear as tiny veins. It is weakly cemented, but the soil material is somewhat porous and the small dry clods are not difficult to crush. The material breaks into irregular-shaped clods without any apparent cleavage planes. This layer is underlain by very pale-brown cemented gravelly hardpan material at a depth of 30 to 48 inches. Between 50 and 70 percent of the material consists of well-rounded water-laid gravel, and the rest consists of heavy silt loam, together with lime-carbonate nodules and fragments that constitute the cementing material to a depth of 6 feet or more. It is slowly pervious to water, but tiny plant roots do not usually penetrate it more than a few inches. The two upper layers are very slightly acid, the rest alkaline.

Practically all the soil is cultivated for wheat. The land is usually seeded in fall, and yields 20 to 35 bushels an acre in normal years. Differences in yields are due largely to differences in depth and organic content and in the rainfall, which is highest near the mountains; other variations are due to availability of moisture, which may be derived from adjacent higher lying lands, or from drifted snow. All the land is farmed by summer fallow methods, but the moderate slopes prevent serious erosion.

Morrow silt loam.—This soil covers extensive areas of undulating to gently rolling uplands northwest, west, and southwest of Pilot Rock. Its total area is 30 square miles.

The soil is shallow, nearly everywhere less than 3 feet deep over basalt bedrock and in many places less than 2 feet, and in some localities very shallow spots and rock outcrops are common. Surface drainage is good, but penetration of moisture is slow.

The 6- to 10-inch surface layer is fairly friable brownish-gray silt loam. The subsoil to an average depth of about 18 inches is brownish-gray or brown firm but fairly friable and somewhat granular heavy silt loam or silty clay loam. Below a depth of 18 inches and continuing to bedrock is brown, tough, heavy silty clay loam or silty clay that has a more or less distinct prismatic structure. Many places have no lime, but in some there is a thin lime-concentration layer just over the bedrock. The lime generally is segregated in light-gray flecks, splotches, or streaks, but in places is rather evenly dispersed through the soil material, giving it a gray tinge.

Having a low moisture-holding capacity, this soil is less productive than the Walla Walla soils and is also somewhat harder to till. Much of it is used for the production of wheat by dry farming, but considerable areas, especially those containing much rock outcrop, are not farmed. Such areas furnish fair grazing for livestock. Wheat yields 5 to 15 bushels an acre, probably averaging 8 bushels or less. Crested wheatgrass probably could be grown to good advantage on this soil.

Morrow silty clay loam.—This is a thin soil on undulating to rolling uplands west and southwest of Pilot Rock. Its total area is 31.6 square miles. It is similar to Waha silty clay loam, of the foothill belt, but occupies somewhat lower and drier localities and is somewhat lighter in color and lower in content of organic matter. A profile in a bunchgrass-covered area about 9 miles southwest of Pilot Rock is as follows:

0 to 3½ inches, brownish-gray friable silty clay loam or heavy silt loam, of a thin platy or fine granular structure and containing many grass roots and a few small stones.

3½ to 10½ inches, rather compact dark brownish-gray silty clay loam, of coarse blocky structure, crumbling readily into medium-fine granules and containing many grass roots and a few small stones.

10½ to 16 inches, compact hard medium to coarse blocky clay of medium- to dark-brown color, with many small rock fragments, especially in the lower part.

16 inches+, basalt bedrock.

This soil is generally slightly deeper than in the profile described, but it has many shallower spots. Scattered rock outcrops or loose stone occur in places. Here and there a thin light-gray limy layer lies immediately above bedrock. The soil is used partly for grazing and partly for dry farming. The areas that have the least rock outcrop and loose stone are those commonly cultivated. Wheat alternates with summer fallow and yields 7 to 15 bushels an acre, averaging about 10. The native bunchgrasses on land that has not been plowed afford fair grazing for livestock. Crested wheatgrass probably could be grown to good advantage on this soil.

Erosion is not very rapid, but any erosion on so shallow a soil is serious in its effects.

McKay silt loam.—This soil lies on old alluvial fans and terraces, mostly between 1,400 and 1,900 feet above sea level. The surface soil is generally slightly darker at higher elevations and nearer the mountains, where rainfall is slightly more than in the lower lying districts. A total area of 18.2 square miles was mapped.

It occupies a belt 1 to 2½ miles wide and 10 miles long southeast of Pendleton, at the foot of the Blue Mountains, immediately below the steeply sloping foothills. The gradient ranges from about 2 to 5 percent, but the relief seems quite flat compared with the adjacent steeper foothills, which have slopes of about 12 to 14 percent.

The 10-inch surface layer is brownish-gray friable and granular noncalcareous heavy silt loam (pl. 4, *A*), which when moist is dark to dusky brown. Between depths of 10 and 13 inches the soil in many places is of similar color, texture, and reaction, which is slightly acid, but the structure is decidedly platy. The horizontal plates range in thickness from mere flakes to about one-eighth inch. Below the platy horizon and extending to depths of 15 to 20 inches the material is of similar texture but slightly grayer, lower in content of organic matter, and alkaline. It is rather firm but contains many pores about the size of needle points and may be easily crushed to a powdery mass. This is underlain by distinctly columnar rather dense noncalcareous silty clay. Because of coatings of colloidal organic matter on the sides of columns and on cleavage planes, the columns appear dark brown to weak brown, but when crushed to a powdery form the color is brownish gray. This material like the two layers immediately above is permeated by many small tubes or root channels, each the size of a pin or needle point. At the base of the columns and continuing to an average depth of about 30 or 35 inches, the material is massive pale-brown mildly calcareous silty clay loam, which grades into pale to very pale-brown material containing many gray veins and mottlings of calcium carbonate. It is a firm but friable porous clay loam layer about 10 inches thick and is underlain by rounded water-worn or slightly angular gravelly materials firmly cemented by light-gray or white carbonate of lime. Most of the gravel is basalt. The gravelly layer continues to a depth of 6 feet or more. The thickness of the soil above the cemented material is variable but is generally between 30 and 60 inches. The depth to the columnar layer is extremely variable, even in short distances. Although it generally occurs within 15 or 20 inches of the surface, in an extended exposure the top of the layer is wavy or billowy and within a distance of a few feet the difference in depth to the layer may be more than 15 inches or the columns may not even occur for a distance of several feet. In some places the heavy columnar material is down about 8 inches, and in a few others it is more than 3 feet below the surface (pl. 4, *B*).

The gravelly subsoil material was probably deposited by streams or flood waters during the glacial period, when runoff from the mountains was unusually high. Part of the material above the gravelly stratum may have been deposited by water, but from lack of gravel and stratification, most of it appears to have been deposited by wind. The comparatively dark color of the soil and its moderately high content of organic matter have resulted from the decomposition of grasses. The development of the heavy columnar clay is probably a result of past conditions of poor drainage, the accumulation of sodium salts, and the subsequent saturation of the soil colloids by sodium. This has led to the deflocculation of the colloids and their concentration to form a claypan.

External drainage is good, and internal drainage, though somewhat impeded by the clay layer, is not poor. The clay does not permit rapid percolation, and especially during spring a number of small wet spots appear in fields where the clay is near the surface. Because of such spots, the surface soil does not dry evenly and does not permit the most desirable conditions for spring seeding, weeding, or tillage.

Along several of the small stream courses that carry intermittent flows of drainage water are strips of recent alluvium ranging in width from a few feet to 200 feet or more, eroded from nearby higher lying areas. Some of the larger bodies are shown on the map and are classified with soils of the Hermiston series, but several smaller bodies are included with this soil. In places the more recently deposited soil material is very similar to Hermiston silt loam, but it is generally rather variable in character. In some places it is calcareous in the surface layer, high in content of ash, and of dark-gray color, though in others it is quite similar to Snow silt loam. Although these strips usually occupy slightly depressed areas, in many places the stream channels have been built up by deposition of sediment and now are level with or slightly above the general level of adjacent lands.

McKay silt loam is practically all cultivated. Summer fallow is practiced, and winter wheat is grown. Yields range from 25 to 35 bushels an acre with an average of about 30. Highest yields are obtained from (1) areas nearest the mountains, where the surface soil contains the highest content of organic matter and the rainfall is slightly more than at lower elevations, (2) areas where the soil is deeper, and (3) areas where drifting snows make more moisture available to crops. Because of the moderate slope, erosion is not very serious on this soil.

LIGHT-COLORED SOILS OF THE SMOOTH TO ROLLING PLAINS AND LAKE TERRACES

The light-colored soils of the smooth to rolling plains and lake terraces—the Ritzville, Sagemoor, and Burke series—occupy somewhat lower and more arid areas than the darker colored Walla Walla silt loam and its light-textured phase. The Ritzville soils occupy a wide belt of smooth to rolling uplands extending southwest from the Oregon-Washington line between State Line and Ring to the angle on the western line of the county at Butter Creek. They also occur on ridges within or terraces bounding the Walla Walla Valley in the northern part of the county. The Sagemoor and Burke soils occur on lake terraces and ridges in the Walla Walla Valley.

The Ritzville soils have developed from fine floury loess and somewhat coarser wind-laid materials. They are underlain for the most part by basaltic bedrock but in places by lime-cemented gravel or silty lake deposits. The Sagemoor and Burke soils are formed largely from silty lake-laid materials.

These soils are for the most part fine and silty and have a floury consistence, although the Ritzville series has fine and very fine sandy loam members. All are light in color and low in content of organic matter and nitrogen but fairly rich in other plant nutrients. The Ritzville soils have floury subsoils, even in the sandier types, and a heavy concentration of lime in the subsoil. The Sagemoor and Burke soils are slightly lighter in color than the Ritzville and generally have lime either in the surface soil or within a foot of the surface. The Burke soils as mapped in this area are characterized by a lime hardpan and a comparatively high content of soluble salts (alkali).

The finer textured and deeper Ritzville soils are used mostly for dry-farmed wheat and usually produce fair yields. Small areas under irrigation produce a fairly wide variety of crops. The shallower and sandier soils of the series are not so well adapted to dry farming, and many areas that have been cleared and farmed are now idle. The sandier areas are rather badly affected by wind drifting if cleared and left bare. The Sagemoor and Burke soils are in areas that are mostly too dry for successful dry farming. Considerable areas of the Sagemoor soils are irrigated and are producing good yields of alfalfa and many other crops. Most areas of the Burke soils are not well suited to farming, and are used only as grazing land.

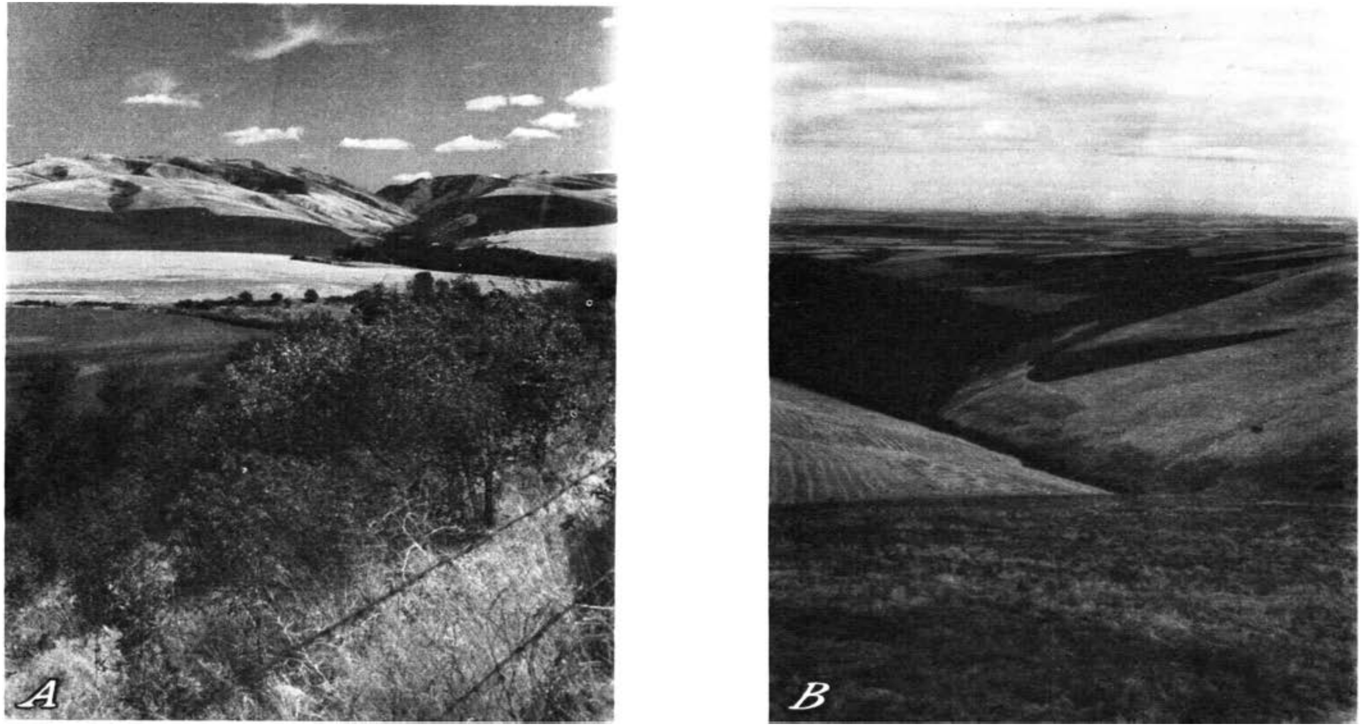
Ritzville silt loam.—This soil occurs most extensively in the west-central part of the area a few miles northeast of Nolin and in the north-central part a few miles southwest of Umapine. It covers a total area of 54.4 square miles. Areas of this soil usually lie immediately below or to the west of areas of the light-textured members of the Walla Walla series. Where outlying bodies are associated with soils of that series, the Ritzville soils usually occupy the steeper slopes of southern or western exposure. In the most extensive areas occupied, northeast of Nolin, the relief is smooth and gently sloping. The tops of the ridges have a gradient of 0.5 to 3 percent. The side slopes leading to the ridge tops are somewhat steeper, and in places have a gradient of as much as 10 percent, as in most of the areas southwest of Umapine that have a strongly undulating to rolling relief.

Ritzville silt loam is developed from fine-textured wind-laid parent materials (loess). The small quantity of organic matter in the surface layer has been accumulated from the native grass vegetation, and a layer of lime carbonate has formed in the soil at about the depth to which water generally penetrates annually. The soil is deep, friable, and sufficiently open to allow good internal drainage. External drainage also is good.

The surface soil of Ritzville silt loam to a depth of 8 inches is pale or light-brown very friable noncalcareous silt loam or loam (pl. 5, *A*), with a faint yellowish tinge. Below this and continuing to a depth of about 19 inches, the material is similar but of slightly lower organic-matter content and is a shade lighter in color. To a depth of 33 inches this is underlain by firm but friable noncalcareous silt loam that contains slightly less organic matter and is slightly lighter in color. Below this layer the material is firm calcareous very pale-brown to light brownish-gray silt loam that has a high content of very fine sand. When moist this soil material is pale or very light brown with a pale-yellowish tinge. It continues to a depth of about 46 inches, below which is a 20-inch layer of heavy silt loam of about the same color. Carbonate of lime in fine-grained or powder-like form with a few soft nodules is disseminated throughout this layer and serves to impart a slight gray tinge. Below a depth of 66 inches and continuing to 7 feet or more, the soil material is soft and mellow, contains less carbonate of lime, is slightly browner, and is silt loam, containing much very fine sand.

The 8-inch surface layer of Ritzville silt loam is slightly acid or neutral, and the rest of the profile is alkaline. The entire soil is friable and has little or no definite structure, has excellent water-

A, Profile of Ritzville silt loam near Echo. The large irregular prisms are very soft and easily crushed. The shovel rests on a layer of lime accumulation. *B*, Gravel pit in Ephrata loamy sand, showing deep deposit under the thin soil.



A, Looking east toward the Blue Mountains from a point near the Washington-Oregon State line, northwest of Milton; Athena soils in the middle distance, Waha and Palouse soils on the lower slopes of the mountains, and rough, stony land on the steeper slopes. *B*, Looking northwest from the foothills of the Blue Mountains to the rolling plain; Waha and Palouse soils on the slopes in the foreground and middle distance, and Walla Walla soils in the background. The dark patches are summer-fallow land. Note tillage on steep slopes holding capacity, and is easily penetrated by both water and plant roots. In areas of grassland the roots are thickly matted in the surface layer to a depth of a few inches, and, although less numerous below, they continue to a depth of several feet. The surface soil is darkest and the content of organic matter is highest in areas of higher elevation where associated with soils of the Walla Walla series.

The areas north of Milton and some of those west of that place differ somewhat from normal. They occupy old terraces, and at least the subsoil materials were presumably deposited on the flood plains of streams or in shallow lake waters. The stratified layers of sediments in the subsoil are generally silty or sandy and in places contain fine gravel. They also contain higher accumulations of mineral salts, which in some places have seeped to the surface on the slopes of the hill. The surface soil in these locations has either lost the stratified appearance while undergoing soil-development changes or wind-laid materials have been deposited on the surface of the lake- or stream-deposited materials. The relief of these areas is smooth and the gradient averages about 100 feet a mile.

A large part of Ritzville silt loam is used for the production of wheat, although about 14 square miles southwest of Umapine and 4 square miles southwest of Nolin are grazed. The predominant crop is spring-seeded Federation wheat, but some Hybrid 128 and Albit and smaller acreages of Federation are seeded in fall. South and southwest of Umapine the yields are 10 to 15 bushels an acre; north and northeast of Nolin, 15 to 20 bushels; and southwest of Nolin, about 10 bushels. These differences result from variations in rainfall, depth and uniformity of soil, and degree of slope.

Summer fallowing is practiced. Some soil blowing occurs in fall, and some gully erosion on the steeper cultivated slopes during periods of excessive runoff. The practice of establishing trashy fallow, which includes disking the stubble in spring and keeping straw mixed with the surface soil, is being tried in an effort to prevent erosion both by water and wind.

Some of the areas used for grazing have medium to sparse stands of bunchgrass, but because of overgrazing, downy bromegrass, together with Russian-thistle, rabbitbrush, sagebrush, mustard, and other weeds, forms the principal vegetal cover. These plants are not highly nutritious, but practically all are eaten to some extent. Sheep are grazed on these lands in winter and early spring only. About 50 acres are required for one animal unit (one horse, cow, or steer or five to seven sheep). Restricted grazing and the seeding of suitable grasses, including crested wheatgrass, would greatly increase the carrying capacity, though the cost of establishing stands of crested wheatgrass is a major consideration and should be carefully considered in comparison with the present value of the range.

Ritzville silt loam, shallow phase.—This shallow phase is associated with the normal soil and with Walla Walla silt loam, shallow phase. It is similar to the typical soil, but the depth over lime hardpan or basalt bedrock is less than 3 feet in most places. It occupies several large areas where the soils are shallow, as well as many smaller areas associated with the Walla Walla soils and the typical soil. These smaller areas are narrow strips, mostly on steep southern or western exposures. The phase is most extensive south of Echo and Nolin, but other bodies are north and northeast of Nolin, between Nolin and Pendleton, and southwest of Pilot Rock. The total area includes 42.2 square miles. In a few places the land is comparatively level, but most areas are somewhat rolling, with slopes ranging from 4 to 8 percent.

The mineral parent soil material is apparently of wind-laid origin. Small accumulations of organic matter have been incorporated in the soil from grasses or other vegetable growth. The relatively small quantity of organic matter is characteristic of soils developed in areas of light rainfall and under medium or thin stands of grasses. Rainfall in sections where this phase occurs is estimated to be 10 to 13 inches. Internal drainage is adequate under natural conditions, although deep penetration of moisture is restricted by the underlying hardpan or bedrock that occurs at a shallow depth. External drainage is good or excessive. Because of generally light rainfall the soil is not seriously eroded.

The 8-inch surface layer is pale- or light-brown soft and almost structureless noncalcareous silt loam, which grades into slightly lighter brown friable noncalcareous silt loam that extends to a depth of about 15 inches. Between 15 and 30 inches the material is slightly firmer noncalcareous silt loam. It stands in a cut bank and will break into soft irregular-shaped clods when dry, but handled when moist it crumbles into an incoherent mass. It is somewhat lighter brown in color and contains less organic matter than the layer immediately above. At a depth of 30 inches or less this material is underlain by pale- to very pale-brown slightly or moderately calcareous friable silt loam or loam that continues to the underlying lime hardpan or bedrock. Depth to hardpan or bedrock ranges from about 1 to 3 feet. In the more shallow bodies the material in many places is noncalcareous except for a very thin gray coating of lime carbonate that occurs on top of the rock. In most places where the soil is deeper it is underlain by a gray or white firmly cemented lime-carbonate hardpan, which in places is a foot or more thick and overlies basalt bedrock, beds of gravel, or semiconsolidated finer alluvial sediments. The reaction of the surface soil is neutral, but below this it is alkaline. The very friable material absorbs water readily, and plant roots are generally numerous throughout the entire soil profile.

Between 7,000 and 8,000 acres of this soil are used for wheat and the rest is grazed. Wheat yields 10 to 15 bushels an acre, depending upon depth of soil and the moisture conditions. In some places the vegetative cover on lands used for grazing consists largely of bunchgrass, but because of overgrazing most of it consists of downy bromegrass, rabbitbrush, sagebrush, Russian-thistle, mustard, and a few other weeds and grasses of minor importance. By seeding the range to crested wheatgrass and exercising caution to prevent overgrazing, the carrying capacity may be greatly improved. The cost of reseeding, however, is considerable. At present about 55 acres are required to furnish grazing for one animal unit.

Ritzville very fine sandy loam.—This soil is most extensive east and northeast of Echo, but many bodies are in and immediately south of the Walla Walla Valley; north and northwest of and near Holdman; near Cold Springs Reservoir; south, southwest, and southeast of Echo; and west of Butter Creek. It has developed mainly under bunchgrasses, and the small accumulation of organic matter causes the surface layer to be slightly darker than the underlying material. A total area of 137.2 square miles was mapped.

The surface is generally smooth and gently sloping or rolling. In Walla Walla Valley and in bodies west of Butter Creek the slopes average less than 1 percent, and in the other areas from 2 to 10 percent or more. Most of the land is smooth enough for cultivation. Near Holdman and in other places where large areas consist of rather steep-sided narrow ridges, the cost of cultural practices is higher than where wider topped ridges with more gentle slopes predominate.

The 8-inch surface layer is a light- or pale-brown friable noncalcareous very fine sandy loam. There is very little evidence of structure other than a fine floury mass. Between depths of 8 and 23 inches the soil is similar to the layer above but is a shade lighter and contains slightly less organic matter. Between 23 and 35 inches is slightly firm but very friable pale- to very pale-brown noncalcareous loam, a shade lighter in texture, and containing slightly less organic matter. This is underlain by friable, mildly calcareous, pale-brown light silt loam that continues to an average depth of 48 inches, where the soil becomes heavier in texture and is very pale-brown to light yellowish-brown silt loam with gray or white lime specks and soft lime-carbonate nodules. This 6-inch layer of high lime accumulation is moderately compact in some places when dry but can be dug with a shovel; in other places the lime carbonate is not so highly concentrated in a definite layer but occurs as finely divided material so evenly distributed throughout the soil that no cementation occurs. At a depth of about 54 inches and continuing to 86 inches is very pale-brown friable moderately or highly calcareous silt loam or heavy silt loam. From a depth of 86 inches to 9 or 10 feet below the surface is pale-brown to light yellowish-brown highly calcareous friable heavy loam or silt loam that represents the parent material.

Depth to basalt bedrock is generally more than 6 feet in most bodies north of the Umatilla River. Between Cold Springs Reservoir, Holdman, and Ring, and for several miles south and southwest of Holdman, the depth to bedrock is generally more than 12 feet. In many of the bodies south and southwest of the Umatilla River the depth of the soil ranges from 4 to 7 feet. In these areas, and more especially in those west of Service Butts and of Butter Creek, the friable light-textured soil is underlain by water-worn stream-deposited gravel and stones that are firmly cemented by carbonate of lime into a hardpan, or caliche. The lime carbonate is usually very dense in the upper few inches or few feet of the gravelly stratum. Below the lime accumulation the gravelly material is firmly compacted. The gravelly stratum, which in some places is more than 20 feet thick, is underlain by basalt bedrock. In the bodies south of the Umatilla River where basalt bedrock underlies the friable soil, a crust of lime carbonate ¼ to 1½ inches thick lies immediately on top of and is cemented to the bedrock. The friable soil that overlies the cemented gravelly substratum or the basalt bedrock has apparently been developed from wind-laid deposits. Some volcanic ash is mixed with the soil material.

In Walla Walla Valley north and west of Milton and Umapine the several areas are somewhat different in character from the more typical bodies of the soil. In that section the subsoil and, in some places, the surface soil are very similar to that of Sagemoor silt loam. The bodies in that vicinity consist of ridges that stand 10 to 20 feet or more above the valley floor. At one time the entire valley floor was about as high as the tops of the ridges are at present, but the waters of the Walla Walla River and its tributaries have eroded extensive areas and formed the present physiographic features of the valley. In some places from 15 inches to 2 or 3 feet below the surface are gray stratified silty and sandy calcareous deposits, apparently laid down by water. These stratified materials continue to a depth of 20 feet or more and contain many comparatively hard seams of silty or clayey material that are in some places high in lime carbonate and other mineral salts and alkalies. The few inches of surface soil are generally neutral in reaction, but the lower layers are alkaline. The subsoil of the bodies near Umapine is decidedly alkaline.

Several areas in Walla Walla Valley that are shown on the map as Ritzville very fine sandy loam do not occupy the higher formations but commonly lie adjacent to them and form low smooth-surfaced gently sloping alluvial fans that range from a few inches to as much as 5 feet or more above the general level of the valley floor. These fans have been built from the accumulation of recently deposited sediments that have been eroded from the higher lying areas. In some places all the materials of the profile have been eroded from the higher lying lands, and in others the subsoil is similar to that of the higher land but the few inches to as much as 3 feet of surface soil consists of recent alluvial sediments, mildly calcareous in places but generally noncalcareous to a depth of 2 feet or more. In general, the texture, color, organic-matter content, and drainage conditions of this variation are very similar to those of the other bodies that occur in Walla Walla Valley. The greatest difference lies in the lower elevation of these areas and consequently in the greater availability of water for irrigation purposes.

This soil is generally very deep, is very friable, has excellent water-holding capacity, is easily penetrated by water and plants roots, and is not difficult to pulverize or cultivate. Plant roots in grass-covered bodies are usually thickly matted near the surface and many continue to a depth of 6 feet or more below the surface. Except for a limited supply of available moisture this soil provides excellent conditions for the growth of plants. The average yield of wheat is less than 20 bushels an acre, although during years when rainfall is heavy and well distributed during the growing season as much as 40 bushels or more have been produced.

About 35,000 acres of the soil north and east of Echo and near Holdman and about 2,500 acres in the Walla Walla Valley are used for the production of wheat by summer-fallow methods. About 1,000 acres in the Walla Walla Valley and a small acreage near Stanfield are irrigated. Alfalfa, the principal crop on this irrigated land, yields 3½ to 5 tons an acre. The rest of this soil is used as range pasture for sheep and cattle, and to a small extent for horses. East of Echo yields of wheat as high as 20 bushels an acre have been produced, but the average yield for that locality is about 15 bushels. In some places to the east and northeast yields range from 15 to 20 bushels an acre during normal years. Differences in yields result from differences in the depth of the surface layers and from variations in slope. The northern and eastern slopes, here as elsewhere in the Umatilla County, produce more grain than the southern or western exposures. In the Walla Walla Valley wheat produces 15 to 20 bushels an acre and averages about 17 bushels. In places where the Sagemoorlike variation of this soil is irrigated in Walla Walla Valley, seepage waters which readily appear on slopes of the hills are so highly charged with salts that crop yields have been materially reduced or the growing of commerical crops has been entirely precluded. Under dry-farming conditions yields on these bodies are less than on the more typical soil.

In some places uncultivated areas of this soil support a medium stand of bunchgrass, but most of the areas, because of overgrazing, support a stand of downy bromegrass, rabbitbrush, sagebrush, Russian-thistle, mustard, and other weeds. Where there are good stands of bunchgrass, about 25 acres are required for one animal unit; but it takes about 45 acres where the stand consists of downy bromegrass, mustard, alfileria, and less conspicuous weeds, grasses, and shrubs. The land is seldom grazed by cattle or horses but is used almost wholly for sheep during the spring and winter months. The most valuable feed in the downy bromegrass sections is during March, April, and early May, though bunchgrass is valuable both for its green growth in spring and as matured grass during the early winter months. The carrying capacity of range lands could undoubtedly be increased by the establishment of good stands of crested wheatgrass or other suitable grasses and by the enforcement of restrictions to prevent overgrazing and minimize soil erosion.

Water erosion on this soil is not very serious compared with erosion on Athena silt loam and Palouse silt loam, which are farther east or southeast, where the rainfall is greater. Soil blowing, however, is serious in some cultivated fields and to some extent on grazing land. To reduce loss of soil, the practice of establishing trashy fallow is being tried by some farmers. Soil blowing in the areas used for grazing occurs mainly where the land is overgrazed.

Ritzville very fine sandy loam, shallow phase.—In soil characteristics, relief, geologic origin of parent material, and in native vegetation, this phase is similar to the typical soil. It is shallower, however, the depth to bedrock being generally less than 3 feet, and the content of organic matter is slightly less than in Ritzville silt loam. The entire soil is friable, it has good water-holding capacity, is easy to cultivate, and is naturally well adapted to the growth of grasses or grasslike plants. In some places where the depth to bedrock is less than 18 inches the soil material is noncalcareous, but usually some carbonate of lime occurs in the subsoils of areas that are 18 inches or more deep. The soil is generally underlain by a firmly cemented lime hardpan that lies over bedrock, gravel, or semiconsolidated finer sediments. In most bodies south and southwest of Echo and west of Butter Creek the underlying rock stratum consists of water-worn gravel, the upper part of which is firmly cemented by gray or white carbonate of lime. In some places the gravelly material overlies basalt bedrock a few feet below the surface, but in others it continues to a depth of 6 feet or more. Internal drainage is somewhat restricted by the hardpan, through which water passes slowly. In places, the substratum of basalt bedrock almost entirely prevents deep penetration of water. As the rainfall, however, is generally less than 10 inches, internal drainage is adequate. External drainage also is adequate to care for the runoff.

The relief is generally smooth but somewhat rolling to ridgy and is such that nearly all the soil could be cultivated. Slopes range from about 2 to 10 percent or more. Like the areas of the normal soil, the bodies west of Butter Creek are comparatively flat and the slope is less than 1 percent. The total area includes 22.1 square miles. A few areas are about 5 miles southwest of Pendleton, several are south and southeast of Nolin, and a few are northeast of Echo, where they occupy slopes and breaks amid large bodies of the typical soil.

Because of the low yields obtained on this shallow soil under the prevailing low rainfall, less than 1,000 acres are cultivated, chiefly in areas about 5 miles southwest of Pendelton, where rainfall is higher than average and wheat yields about 10 bushels an acre. The other areas support mainly downy bromegrass, rabbitbrush, sagebrush, Russian-thistle, mustard, and other weeds. Sheep and cattle are grazed in winter and spring. About 55 acres are necessary for one animal unit, but the range could be greatly improved by restricting the number of animals allowed to graze on it. Soil blowing from overgrazing has lowered the productivity in some places.

Ritzville fine sandy loam.—This soil occupies 7.5 square miles mostly in several bodies southwest of Echo, near Butter Creek School, and some a few miles northwest of Holdman. The surface is generally smooth, although some areas are on broad ridges and consequently somewhat rolling, but none is too steep to cultivate. The mineral materials from which the soil has developed originally consisted largely of wind-laid deposits. In some places the drainageways are several feet below the general level of the surface, but the waters that have eroded the channels came from extensive higher lying areas. Other than these, there are only a few drainage channels within the soil areas, as most of the rain is absorbed by the soil as rapidly as it falls. The vegetation consists of downy bromegrass, rabbitbrush, sagebrush, Russian-thistle, mustard, and other weeds and grasses that thrive following spring rains.

The 8-inch surface layer is pale-brown friable noncalcareous fine sandy loam with a low content of organic matter. Beneath this to a depth of about 30 inches the material is similar, but it is slightly lighter in color and slightly lower in content of organic matter. This is underlain by a light yellowish-brown to pale-brown mildly calcareous friable and nearly structureless or floury heavy fine sandy loam that extends to a depth of about 36 inches. The layer of highest accumulation of lime carbonate occurs between 36 and 60 inches. The calcareous material is light brownish-gray friable fine sandy loam, the gray resulting from the uniformly distributed powdery lime carbonate. Below a depth of 60 inches the mineral material appears to be almost unaltered loess. It is moderately calcareous friable fine sandy loam but contains less lime carbonate than the layer immediately above.

The 8-inch surface layer is neutral, but the lower layers are alkaline, the most alkaline being the layer with the high accumulation of lime carbonate between depths of 36 and 60 inches. The entire soil is friable, is easily penetrated by plant roots, absorbs water rapidly, but has only a medium or low water-holding capacity. Roots of grass or brush penetrate 6 feet or more below the surface.

Northwest of Holdman, where associated with finer textured soils, about 200 acres are cultivated and used for growing wheat. Yields, however, average less than 15 bushels an acre, and considerable blowing of surface material is detrimental both to the cultivated fields and to the adjacent areas upon which sands have drifted. Such land should be seeded to crested wheatgrass or some valuable permanent grass. Except for the 200 acres farmed, the soil is used for grazing sheep in winter and spring. In winter some weeds and shrubs are browsed, and usually some grain or hay is supplied, but in spring downy bromegrass, many weeds, alfileria, and less conspicuous weeds and grasses provide valuable feed for sheep. About 45 acres are required for one animal unit. The range could be improved by restricting grazing to prevent soil blowing and to preserve the stand of grass.

Ritzville loamy fine sand.—This soil is similar to Ritzville very fine sandy loam, with which it is closely associated, in practically all characteristics other than texture and a slightly lower content of organic matter. It occurs in many bodies extending from near Echo to the State boundary northeast of Holdman. The total area of 20.8 square miles is mainly just west of large bodies of Ritzville very fine sandy loam. Areas may also occur elsewhere adjacent to that soil or on steep slopes where considerable wind erosion has occurred. The rainfall is slightly less than the average in districts where Ritzville very fine sandy loam is extensive.

The texture of the surface soil is loamy fine to very fine sand, and below a depth of about 20 inches it is very fine sand. Like the Ritzville very fine sandy loam, this soil is deep, friable, and contains a layer of accumulated lime carbonate at about 30 to 36 inches below the surface. The lime continues downward in finely divided uniformly disseminated form through the soil and is responsible for the grayish cast of the subsoil.

This soil is easy to cultivate, absorbs moisture readily, is easily penetrated by plant roots, and has fair water-holding capacity. It has developed under conditions similar to those on Ritzville very fine sandy loam and Ritzville silt loam, although the stands of native grasses were thinner. This probably is because of slightly coarser texture, slightly less rainfall where this soil occurs, and to some shifting of the surface soil, which is unfavorable to plant growth. In places the boundary between this soil and the Ritzville very fine sandy loam is that between land suitable for wheat raising and that for range. The combined effect of slightly less rainfall, greater susceptibility to blowing, and slightly less organic-matter content are such that growing wheat on this soil is generally more or less uncertain. About half the area, however, is cultivated, and yields are fair to good when moisture conditions are unusually favorable.

The bodies surrounded by heavier textured soil are usually cultivated by summer-fallow methods. Wheat yields range 10 to 15 bushels an acre in normal years. Some of the grazing lands support a medium to sparse stand of bunchgrass, but because of overgrazing, most of this has been replaced by downy bromegrass, rabbitbrush, sagebrush, and other weeds and grasses. About 50 acres is the average to support an animal unit, but the grazing capacity could be increased by preventing overgrazing.

Unless adequate control methods can be adopted to stop soil blowing, loss of the most fertile surface soil and reduced yields will eventually force farmers to cease cultivation. All the straw from a wheat crop should be returned to the soil.

Sagemoor silt loam.—This soil occurs in the Walla Walla Valley, where 6.1 square miles are mapped. The surface is smooth, slightly undulating, or rolling, and the prevailing slopes range from about 1 to 3 percent, although they are steeper in places. The soil is developed from finely laminated fine sand, silt, and clay strata that probably were deposited in and around the margins of former lakes or from such strata modified later by either stream- or wind-laid sediments.

Water from adjacent higher-lying lands has cut drainageways through the soil in some places, and in others incipient drainage courses have been established, but rainfall is low, and practically all moisture is absorbed as rapidly as it reaches the soil. Native vegetation includes sagebrush, rabbitbrush, weeds, and grasses.

The surface soil to a depth of 13 inches is pale-brown or brownish-gray friable noncalcareous silt loam. Below this, very pale-brown rather firm but soft moderately calcareous loam or silt loam continues to a depth of about 38 inches, where it is underlain by very light brownish-gray highly calcareous loam or silt loam in the form of flattened lenses and weakly cemented by carbonate of lime. This material, which contains a few strata or lenses of somewhat firmer or weakly cemented material, is underlain by very light brownish-gray friable highly calcareous loam at a depth of about 48 inches.

This soil and its parent material are easily identified in road cuts or where the profile is exposed. In addition to horizontal stratification there is usually a peculiar wavy bedding and occasionally vertical fissures or cracks extending downward for many feet and filled by material washed from the surface.

The surface soil has a slightly alkaline reaction, and the subsoil is decidedly alkaline. Because of the modification of the surface soil by plant roots and slight accumulation of organic matter, the material is very friable and the original stratification has been obscured. The subsoil, however, is slightly compact and usually very much stratified with silt loam or very fine sandy loam material. Rarely, strata contain a little fine gravel. The soil is high in its content of mineral salts, and in many places these are concentrated on the surface either on slopes or on comparatively level lands below them. On slopes and to some extent in other places, water percolating through the subsoil is forced to the surface by comparatively compact, dense, or finer textured strata, and as it evaporates it leaves salts on or near the surface.

The soil is not used for dry farming but mainly for grazing. Where irrigation water is available, alfalfa is the principal crop. The soil is not difficult to cultivate, but because of a large percentage of silt and very fine sand, care must be exercised when irrigating sloping lands to prevent erosion and the formation of gullies. Comparatively hard strata that have formed in the subsoil appear at the surface on slopes and retard the penetration of both roots and irrigation water. Alfalfa yields 2 to 4 tons an acre and averages about 3 tons. Because of the low rainfall, the vegetation consists largely of brush, with a sparse stand of grass, and about 50 or 65 acres are required to support one animal unit.

Burke silt loam, saline phase.—This soil differs from Sagemoor silt loam principally in that the surface soil usually contains larger quantities of mineral salts and the subsoil is characterized by a cemented layer commonly referred to as a hardpan. It occurs in the Walla Walla Valley, west, northwest, south, and southwest of Umapine, but several bodies occur southwest of Echo and near Service Buttes, and there is one 4 miles east of Echo. A total of 2.8 square miles is mapped.

The surface is generally smooth and gently sloping or slightly undulating, and the few drainage channels are not of recent origin. In most places only incipient drainageways are formed, as most of the moisture is absorbed as it falls. Seepage waters pass laterally above the hardpan and reach the surface in some places, but as the rainfall is light this condition is not serious. If the land were irrigated it would aggravate seepage, temporary waterlogging, and accumulation of salts at the surface in many places.

A moderate or dense stand of greasewood 1½ to 3½ feet high forms the principal vegetal cover in areas most highly affected by accumulations of salt. Other salt-affected bodies, where appreciable seepage water is close to the surface, are covered with saltgrass. Bodies free from high accumulation of salts support a moderate stand of sagebrush, rabbitbrush, downy bromegrass, and some weeds.

The 6- or 8-inch surface layer is pale-brown or brownish-gray friable slightly compact silt loam. Where salt concentration is high this is usually calcareous, but elsewhere it is generally free from an excess of lime carbonate. Below this and continuing to depths ranging between 1½ and 5 feet are stratified gray or very pale brownish-gray mildly or moderately calcareous slightly compact materials that are very low in content of organic matter. These are underlain by a lime-carbonate hardpan 1 to 6 inches or more thick that may occur as one rather evenly cemented layer, or it may consist of many thin or thick lenses separated by slightly less cemented and more friable or gritty material. Below the hardpan and continuing to a depth of 6 feet or more are layers of gray slightly compact calcareous materials that range from loam to clay in texture. Occasionally one hardpan layer occurs in the upper 3 feet of soil and another between 3 and 6 feet. Both surface soil and subsoil are highly alkaline. Where the soil is free from high concentrations of salts, the surface soil contains many plant roots and fine roots spread out on top of the carbonate hardpan. Rain water is usually absorbed by the soil as fast as it falls. The cemented layer is usually so hard that a soil auger must be sharp to drill through it, but the material is somewhat porous and slowly penetrable to moisture.

Most of the bodies located in the western part of the area differ from the more typical soil in the Walla Walla Valley in that the parent material generally consists of sediments of wind-borne origin (loess) instead of alluvial or lake-laid materials. In these places the surface soil above the hardpan is browner and has a higher content of organic matter than that of the typical soil, and the subsoil below the hardpan is not highly stratified but consists of pale-brown or grayish-brown highly calcareous loam or very fine sandy loam. The salts have been washed from adjacent higher lying soils and later deposited in or near the surface of this soil. In places the soil has a well-developed brown claypan above the lime hardpan.

None of the soil is cultivated; it is used only for pasture. The carrying capacity is variable. Where seepage occurs and saltgrass thrives, about 3 acres are required for one animal unit. More than 60 acres are required in areas where sagebrush and downy bromegrass predominate, and the bodies that support principally greasewood are of almost no value for grazing.

With an adequate supply of irrigation water some areas could be reclaimed, though the cost of reclamation for other areas in which the hardpan is dense and close to the surface would probably not be justified by crop returns over a long period of years. Steeply sloping areas would be particularly hard to reclaim.

DARK-COLORED SOILS OF THE FOOTHILLS AND LOWER MOUNTAINS

The dark-colored soils of the foothills and lower mountains—the Palouse, Waha, and Thatuna series—occupy an irregular belt extending in a northeast-southwest direction across the foothills and on the lower slopes and ridges of the Blue Mountains, where the annual rainfall is about 20 to 30 inches. These dark fertile soils contain relatively large quantities of organic matter (humus) and are very slightly acid.

The Palouse soils are dark brownish-gray to nearly black granular silt loams with rather heavy-textured but fairly permeable subsoils. They appear to have developed largely from loess under a cover of bunchgrasses. The Waha soils, somewhat shallower and heavier in texture and with heavier and tougher subsoils, occur on exposed hilltops and windward slopes and in places are very thin over bedrock. The parent materials are partly residual from the underlying basalt and partly loessal. The Thatuna soils are somewhat lighter colored than the Palouse and Waha and lie at somewhat higher elevations in the lower edge of the belt that originally supported an open growth of western yellow pine with considerable bunchgrass and some brush. They range from medium brown to dark brown or dark brownish gray. The soil materials probably consist of loess in the upper part and of residue from basaltic bedrock in the lower part.

The soils of these series are well suited to the production of wheat, and most areas are suitable for growing peas for canning. The Thatuna soils, which receive somewhat more rainfall than the Palouse and Waha, are used also for the production of potatoes. The shallower Waha soils have lower moisture-holding capacity and are less productive than the other series.

Palouse silt loam.—This soil occurs in an almost unbroken belt that averages about 2½ miles wide extending from Weston northeastward to the margin of the area and southwestward to the Umatilla River near Cayuse, and several smaller bodies are in the foothills to the east, south, and southwest. The total area mapped is 15.9 square miles, on the higher parts of the more level plains and on the slopes of the foothills (pl. 3, *B*) where the plains merge with the mountains and where the annual rainfall is about 20 to 25 inches. In the foothills or lower mountains, bodies of this soil occupy rounded but narrow ridge tops or comparatively steep hillsides, with slopes of 15 to 20 percent or more, although most of the steeper areas have been mapped as a steep phase. In the lower districts, topographic features consist of a series of ridges or rolling areas with slopes of 5 to 15 percent (pl. 6). The parent material is derived from loess.

The 4-inch surface layer is dark brownish-gray or brownish-gray heavy silt loam, which when moist is brownish black or dusky brown. Usually this layer is so densely matted with roots that the structure is difficult to determine, but in places it consists of thin, very friable platy material that when crushed breaks into fine granules. Below this to a depth of about 21 inches the material is of similar color, consistence, and texture, but is granular rather than platy. Between depths of 21 and 24 inches is a second layer of platy material in which the plates are more generally distributed and more distinct than in the topmost 4-inch layer. This layer is also similar in color and is firm but friable slightly granular heavy silt loam. The platy layer is underlain by material of similar color and texture, but of prismatic structure. The prisms are not uniform in size but vary from about 1½ to 4 inches on the sides and continue downward to about 40 inches below the surface, though they become less distinct and may be lacking or almost lacking in the lower parts. At a depth of about 30 inches the comparatively dark organic-stained material grades into material that is weak brown when dry and dark brown to dusky brown when wet. Individual prisms may be removed if carefully handled, but they are easily crushed to small clods and fine granular material. At the lower extremity of the prisms, or from an average depth of about 44 to 55 inches below the surface, is a weak- to pale-brown firm but friable silt loam or silty clay loam. The structure is indistinct, but under pressure the mass breaks into clods or granules. Below this is a light yellowish-brown firm but friable heavy silt loam or silty clay loam. A few basaltic rock fragments occur in the lower material, usually at a depth ranging from 12 to 30 inches above the hard bedrock, which commonlly occurs at a depth of more than 8 feet.

The reaction is very slightly acid or nearly neutral to a depth of 4 feet or more. In places below this depth enough lime occurs to cause slight effervescence when dilute hydrochloric acid is applied. Plant roots are numerous in the darker upper part of the soil, though many extend to a depth of 55 inches and a few even below 6 feet. The entire soil is comparatively friable and contains appreciable pore space throughout the profile. Holes the size of a pin point permeate the prismatic and lower layers. In many places the dark color does not extend so deeply as described, and the lighter-colored material, which is lower in humus, occurs at about 24 inches below the surface. Palouse silt loam merges with Athena silt loam at the lower elevations.

External and internal drainage are good under natural conditions, but under cultivation absorption of moisture is slow in many places. Cultivation destroys vegetative cover to such an extent as to leave practically no trashy undecomposed material exposed. The mulch

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caused by such cultivation does not allow so rapid penetration of moisture as does the surface soil under grass or native cover. In many places, especially on the steeper slopes, during periods of exceptionally heavy rainfall or of melting snow, much water is lost from the soil as runoff, and washed away with it is some of the fertile surface soil. In some places practically all surface soil has been removed and the subsoil is exposed.

The native vegetation under which this soil developed was principally bunchgrass, but practically all of it has been destroyed by cultivation.

Because of the unusual depth to which organic residues have accumulated, this soil is potentially one of the most fertile in the area. Climatic conditions are favorable for wheat and peas, and many farmers alternate the two. In general, however, wheat is alternated with summer fallow on a considerable part of the area and peas are grown alternately on a somewhat smaller area. Wheat yields 35 to 60 bushels an acre, averaging about 45. Peas yield 500 to 3,000 pounds an acre, with an average of about 2,400. The yield of wheat is highest on the more level areas north and northwest of Thorn Hollow, where during favorable years 60 bushels are obtained. On steeper areas near Weston and both south and northeast of the town, yields average more nearly 40 bushels. The usual methods of summer fallow and fall planting of wheat predominate, although growing peas instead of the summer fallow is becoming more common. An effort is being made to encourage cultivation with the contour and to control runoff and destructive soil erosion.

Palouse silt loam, steep phase.—This phase lies on rather narrow steep slopes in the foothill belt, where the gradient in most places of 30 percent or more renders the land practically nonarable because of the difficulty of handling farm machinery and controlling erosion. It is similar to the typical soil, but generally thinner. Mostly in bunchgrasses and brush, its best use is for pasture. The total area is 1.5 square miles.

Waha silty clay loam.—This soil occurs in the foothills in association with Palouse soils and in the mountains to the east and south, generally occupying slopes with southern and western exposures. The total area mapped is 44.2 square miles. The surface is generally smoothly sloping, but the soil occurs in the hilly or mountainous districts where slopes of the ridge tops range from 5 to 15 percent and the side slopes from 10 to 30 percent or more. Most of the areas can be cultivated, although a few are so steep that cultivation is difficult.

The soil has probably developed in part from wind-borne material, but the heavy-textured subsoil probably is the residue from weathered basaltic bedrock similar to that underlying the soil. The native vegetal cover consists mainly of bunchgrasses.

The surface soil of about 5 inches is brownish-gray to dark brownish-gray friable granular silty clay loam over a subsurface layer of similarly colored coarsely granular or fine blocky silty clay loam or silty clay that continues to a depth of about 10 inches. When moist these two upper layers are brownish black or black. Below about 10 inches is a compact heavy silty clay loam or silty clay that is weak brown when dry, and dark brown or dusky brown when moist. In cut banks that have been exposed for long periods this appears to have a somewhat prismatic structure, but when crushed breaks into irregular blocks varying from the size of a pea to that of a marble. Fine tubes or root channels about the size of a fine needle point characterize this material. The irregular-shaped cleavage surfaces are stained slightly with dark organic residues, but when the blocks are crushed to a powder the color changes to pale brown or light brownish gray. This layer averages about 8 inches in thickness and at a depth of about 18 inches is pale-brown or moderately yellowish-brown compact silty clay that usually contains a few fragments of basaltic rock. This layer continues to bedrock, the depth to which commonly ranges from 21 to 38 inches. The entire profile is slightly acid in reaction.

The darker surface layers are comparatively rich in organic residue, and plant roots, which are thickly matted in the topmost few inches, are numerous to 18 inches below the surface. A few fine roots penetrate the clay and continue to bedrock, the depth of which is not more than 10 inches below the surface. In the shallower areas, occasional rock fragments are scattered over the surface and mixed throughout the soil.

Several bodies south of Athena that are associated with Walla Walla silt loam have surface soils that are lighter in both color and texture than is generally typical. The surface soil is heavy silt loam in the area at the center of sec. 34, T. 4 N., R. 35 E., and also in most of the area mapped in sec. 3, T. 3 N., R. 35 E. Cultivation is less difficult in these bodies than in the bodies that have the more typical silty clay loam texture. Also in the vicinity of Pilot Rock, several bodies have been included that are not typical. In the areas of lower elevation in that vicinity, the soil is brownish gray, is comparatively low in humus, and is less productive than the typical soil. Several of these areas are in T. 1 S., R. 32 E., one is in section 12, and includes most of the northern part of section 13; and another includes the western two-thirds of section 23, as well as the body in section 22, about the northwestern one-third of the body in section 26, and the body in section 27. The areas in section 4, in the center of sec. 10, T. 2 S., R. 32. E., and in the western part of the sec. 7, T. 1 S., R. 33 E., are also lighter in color and produce less than the typical soil.

Most of this soil is cultivated, and though the heavy texture and occasional rock fragments make it more difficult to cultivate than most soils, if it is plowed when moisture conditions are favorable the costs are not excessive. Wheat is the principal crop (pl. 7, *A*), peas are important, and native or seeded grasses are used for pasture on some of the very shallow areas. Wheat is usually seeded in fall and yields 10 to 35 bushels an acre. Yields in the several bodies in the almost extreme southwestern part of the area average about 18 bushels an acre. The effects of soil depth have a marked influence on yields of wheat. Where the soil is 3 feet deep, yields are as much as 35 bushels or more, and where not more than 12 inches of soil overlies bedrock they may not exceed 10 bushels. The comparatively high average yields are due in part to the very favorable climatic conditions. The rainfall in sections where the more typical soil is located ranges from about 23 to 30 inches.

Peas, produced only in the areas in the vicinity of Weston, yield 800 to 2,500 pounds, with an average of about 2,000 pounds during favorable years. Depth of the soil does not influence the yield of peas to the same degree as it does wheat because peas are growing only a few months and do not so nearly deplete the soil of its moisture. A limited acreage of crested wheatgrass has been harvested.

The usual cropping practices are wheat and summer fallow, peas and summer fallow, or peas after wheat. Some farmers plant strips of mixed grasses with alfalfa at contour levels to control destructive erosion, and others seed shallow areas to crested wheatgrass. Gully erosion is serious in many places because of the comparatively heavy runoff on steep slopes. The surface soil has been washed from many of the steeper fields, leaving many rock fragments and exposing the compact clay subsoil.

Waha silty clay loam, deep phase.—This deep phase occurs in the foothills and lower mountains in association with Waha silty clay loam, Palouse silt loam, and Thatuna silty clay loam, but it is usually slightly higher in elevation and subjected to slightly higher rainfall than the Palouse soils. The total area is 10 square miles. The relief is generally smoothly rolling or hilly with gradients of 5 to 15 percent. The soil has developed in part from wind-laid deposits, although the heavy-textured layers probably have been developed from basaltic bedrock underlying. External and internal drainage are adequate, although deep penetration of moisture is slow. The native plants that grew on this soil during its development were mainly bunchgrasses.

The 6-inch surface layer is brownish-gray to dark brownish-gray friable granular silty clay loam. Beneath this is similarly colored coarse granular or fine blocky silty clay loam that continues to depths of 10 to 16 inches below the surface. This material is underlain by compact fine blocky silty clay that is weak brown when dry and dark brown when moist. The irregular-shaped blocky aggregates are slightly stained or coated with humus, which imparts the brownish cast. When the material is very finely crushed the color is pale brown or light brownish gray. It averages about 8 inches in thickness and grades downward into a layer of pale-brown or moderate yellowish-brown slightly compact silty clay, which continues to a depth of 3 feet to more than 6 feet and is underlain by basaltic bedrock.

The soil is slightly acid in all layers. The dark-colored layers are comparatively high in organic material and nitrates. The many fine plant roots penetrate the heavier textured subsoil, and a few are found near bedrock, or as deep as 5 feet below the surface.

In many areas of higher elevation it is difficult to determine the boundary between this soil and Thatuna silty clay loam, which it resembles in those and a few other places where this soil receives runoff from adjacent higher lands. At depths of 2 feet or in places at 3 feet below the surface, a 1- or 2-inch layer of friable gray ashy material occurs, in some places appearing only as gray mottlings immediately above the brownish-gray or yellowish-brown layer of compact silty clay.

Practically all this soil is under cultivation. Wheat occupies the largest acreage, but in 1937 peas for canning occupied almost as much. The practice of raising peas after wheat or summer fallow alternately with wheat is followed. Federation wheat is usually planted in fall and yields 30 to 45 bushels, averaging 35 bushels. The high fertility of this comparatively dark soil together with an average rainfall of about 25 inches is unusually favorable for the production of wheat and peas. Erosion is serious on steep cultivated slopes that have no protection. Sheet erosion is not severe, but during periods of heavy runoff from melting snow or heavy rainfall summer-fallowed or barren fields are often scarred by incipient rills. The rills are smoothed and filled by cultural practices during the preparation of the land for another crop, but on every hillside where such erosion occurs the potential fertility is lowered by each loss of the dark-colored surface soil.

Waha silt loam.—This soil is developed under conditions very similar to those that give rise to Palouse silt loam, except that the areas are usually slightly more elevated and are subject to a slightly higher rainfall. The shallowness of the soil over the underlying basaltic rock is another characteristic that distinguishes it from Palouse silt loam. Many small areas are on the lower mountain slopes that extend from near the Oregon-Washington line to south of Pilot Rock. The total area mapped is 8 square miles. Most of the relief is smoothly sloping with slopes that range from 5 to 25 percent. The upper part of this soil has been developed largely from wind-laid deposits, but the lower part is residue from basaltic bedrock. External drainage is good to excessive and internal drainage is adequate. Cultivation or overgrazing has decreased the rate of percolation to such an extent that the loss of moisture and surface soil during periods of heavy runoff from rains or melting snows has seriously lowered the productivity and value of the land in many places.

The surface soil to a depth of about 15 inches is brownish-gray or dark brownish-gray friable and granular heavy silt loam or light silty clay loam that contains many roots of bunchgrasses. Between 15 and 25 inches the soil is similar to that of the surface layer, but it is not so dark or granular. This material has many irregular-shaped pore spaces the size of a pin point. Below an average depth of 25 inches and continuing to bedrock is a moderate to pale yellowish-brown firm but friable heavy silty clay loam that contains pore spaces and some fine roots. Bedrock is usually at a depth of 3 feet or less. In different places, however, it may occur at various depths between 10 and 36 inches below the surface. The entire soil is slightly acid or neutral in reaction.

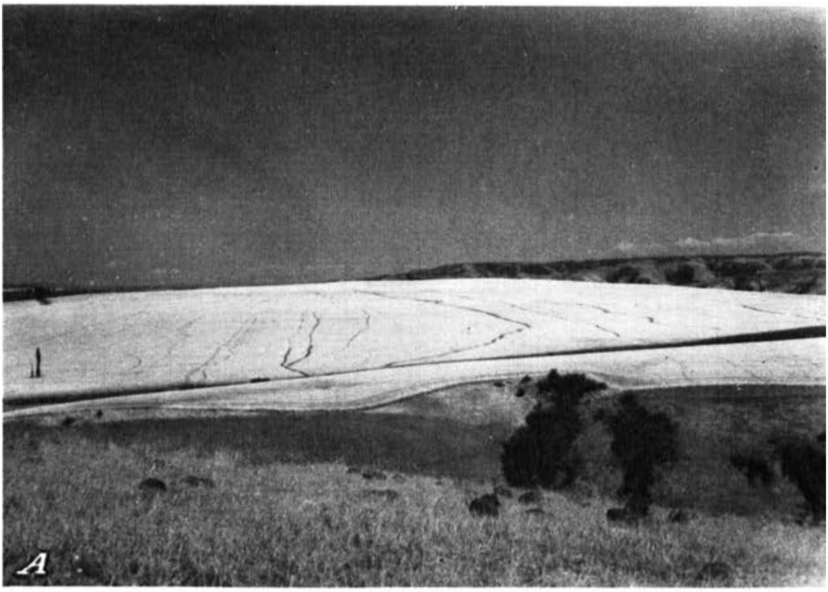
The principal use of Waha silt loam is wheat production. A few areas are used for growing peas, and others for grazing. About 75 percent of the soil is used for cultivated crops. Pasture consists mainly of bunchgrass and downy bromegrass. The soil is well supplied with organic residues and is satisfactorily productive, but because of the shallow depth the yields cannot be expected to be greatly increased by improved methods of management. The rainfall and temperatures in the sections where the soil occurs are rather favorable for both wheat and peas, and yields are generally good. Wheat yields 15 to 30 bushels an acre, depending upon soil depth to bedrock, and averages about 22 bushels. Peas yield 300 to 2,500 pounds, with an average of about 1,800 pounds in favorable years. The common rotations are wheat and summer fallow or wheat and peas. On steep slopes some losses from erosion occur. A few farmers plant strips of alfalfa or crested wheatgrass in an effort to control erosion.

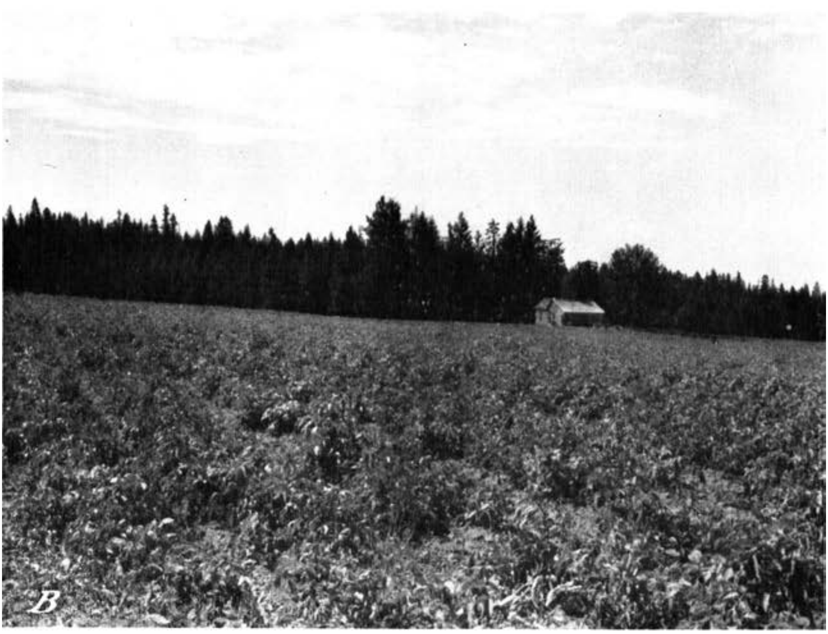
Waha silt loam, deep phase.—The deep phase of this soil occurs in association with the typical soil, but occupies more level or pocket-like areas where the surface runoff is usually not so rapid or where moisture has been derived from adjacent lands of higher elevation. The largest body is about 2½ miles south of Weston, and other bodies are in that vicinity—about 1½ miles north of Thorn Hollow and about 4 miles southwest of Little Meadows. A total area of 1.3 square miles is mapped. The slopes are usually less than 5 percent. The parent material from which the upper part of this soil has developed is largely of wind-laid origin, but the subsoil material may be largely residue from basaltic bedrock. External and internal drainage are good. The native vegetation consists principally of bunchgrasses.

The surface soil to an average depth of 24 inches is brownish-gray or dark brownish-gray granular friable heavy silt loam or light silty clay loam. When the soil is moist the color is brownish black. Between 24 and 44 inches the material, though granular when crushed, is of coarsely prismatic form in place. The outlines of the prisms are more distinct in the upper two-thirds of this layer than in the lower one-third, where they merge with material of indistinct or massive structure. The upper part of the coarse prisms, from 24 inches to 30 inches, is a weak brown and the lower part a pale brown. The texture is silty clay loam. Pale yellowish-brown clay of indistinct structure occurs at an average depth of about 4 feet. This layer of clay continues to a depth of 6 feet or more, or to the underlying basaltic bedrock, though in some places it is underlain by slightly more friable pale yellowish-brown material of silty clay loam texture. The entire profile is either slightly acid or neutral in reaction. Plant roots are numerous in the upper or darker soil material, many occur immediately above the layer of clay, and several small roots penetrate into or entirely through the heavier layer of clay. Pore spaces, about the size of a pin, permeate the clay or silty clay loam of the subsoil and allow free percolation, aeration, and oxidization.

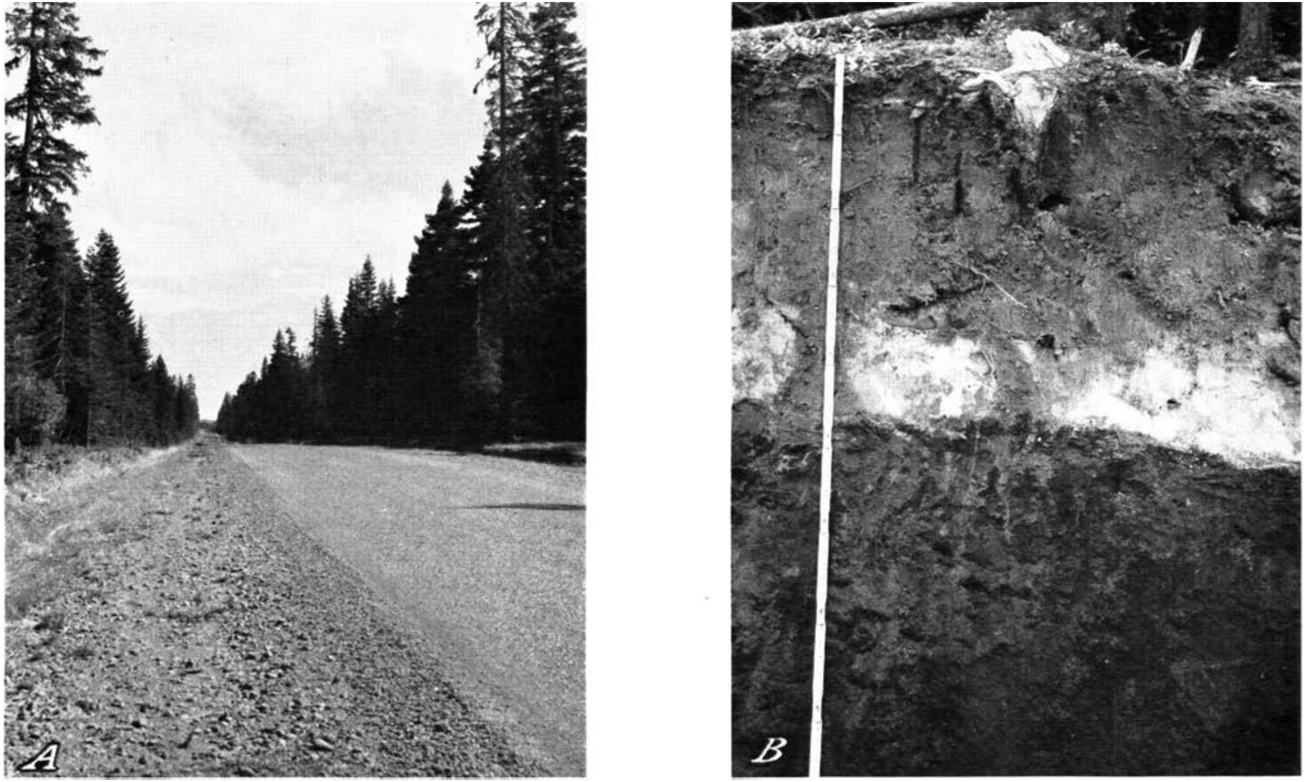
Practically all this soil has been plowed and is now producing wheat and peas. Wheat yields average about 45 bushels where summer fallow is practiced, and peas yield about 2,800 pounds if the season is favorable. Peas for canning, in this section and in the sections farther westward, must mature sufficiently before severe hot weather to escape overripening and withering. Farm management systems include wheat and summer fallow or wheat after peas. Because of the slight slope, erosion has not been serious under these farming practices.

Thatuna silty clay loam.—This soil has developed in areas covered by an open stand of pine trees and grass. Where the pines were most dense, the surface soil is lighter in color, and where practically no pines have stood it is darker than typical. The total area of 6.7 square miles of this soil includes several bodies that are from small to moderate size and located in mountainous districts, east, northeast, and southeast of Weston, and a few small bodies that are in the extreme northeastern part of the Umatilla area. In some places the slope is rather steep, but most of the areas are smoothly or gently sloping and are favorable for cultivation. The parent material is largely of wind-laid origin, though the heavier material of the subsoil may have developed from the basaltic rock that underlies all areas. External drainage is good, and internal drainage, though slightly re-





A, Wheat stubble on slopes of Waha soils near the foot of the Blue Mountains. Considerable gully erosion takes place on dry-farmed areas. *B*, Soils of the Helmer, Couse, and Thatuna series on a small farm on Weston Mountain.



A, Heavy stand of timber on Helmer silt loam in the Blue Mountains east of Weston—spruce, fir, Douglas fir, and tamarack.
B, Profile of Helmer silt loam: A thin dark-colored surface mat, a thick fluffy silt loam layer, a nearly white ashy layer, and a dark-colored heavy compact blocky subsoil.

stricted, is sufficient for all practical purposes. In virgin areas the native vegetation consists of scattered pines and grasses.

The 8-inch surface layer is weak-brown friable granular silty clay loam. When moist it is brownish black and sticky. It is slightly acid but is relatively high in content of organic matter and available nitrogen. A weak- to pale-brown somewhat granular silty clay loam occurs below 8 inches and to a depth of about 27 inches. This layer contains a moderate quantity of organic matter but not so much as the surface soil. Between 27 and 42 inches is a pale- or very pale-brown silty clay loam that is slightly granular and low in content of organic matter. The surface soil to a depth of 8 inches is slightly acid; the second layer from 18 to 27 inches is slightly less acid; and the third layer from 27 to 42 inches is nearly neutral. Below an average depth of 42 inches and extending to about 49 inches is a very pale-brown firm but friable silty clay loam. This layer has been leached of organic residues as well as the more soluble minerals and probably of some of those less soluble. It is underlain by slightly compact light yellowish-brown silty clay that contains many tiny perforations and breaks into irregular-shaped blocks, the faces of many of which are stained with dark colloidal material. When the material is crushed it appears much lighter in color. This heavy-textured layer continues to bedrock, or to depths of more than 6 feet below the surface. Lime carbonate has been leached from the entire soil. Plant roots are very numerous above 42 inches, though many appear below this depth and a few penetrate to a depth of 6 feet or more.

Practically all of the more favorable slopes have been cleared and are now producing wheat, peas, and potatoes. Approximately a half to two-thirds of this soil has been used for growing wheat, and the rest of the cultivated part for peas and potatoes. More recently, however, a much larger proportion of the land is being used for the production of peas. The usual rotation is to grow wheat for 2 years and potatoes the third year. Federation wheat is seeded in fall and yields 20 to 25 bushels an acre, depending upon depth of the soil, season, and other factors relating to care and management. Irish Cobbler and Netted Gem varieties of potatoes are grown, and yields range from 100 to 150 bushels, with an average of about 120 bushels (pl. 7, *B*). The practice of raising potatoes every third year has helped to maintain yields and has given protection against disease. At present no diseases are serious in the area. Practically all this soil is cropped each year. There are, however, a few bodies at the western limits of the occurrence of this soil where summer fallow is practiced. Where this is done wheat yields 50 to 55 bushels.

During the past few years peas have been raised for canning, and a comparatively small acreage is planted to wheat or potatoes. The late-maturing pea varieties, principally Perfection, and to a lesser extent, Early Surprise, are produced. Seeding is done about June 1 at the rate of 135 pounds an acre. Acre yields of green peas average about 2,400 pounds. Thatuna silty clay loam is well suited to the production of peas. They are cool-weather plants that need an abundance of moisture, and they do best where a slow uninterrupted growth of vines is assured. This soil is relatively high in organic matter, is sufficiently deep to store moisture, and provides conditions favorable for uniform stands, growth, and ripening. Peas for canning are harvested about the middle of July. They are cut with a mower equipped with side delivery rake and are immediately loaded on sleds and hauled to viners that are set up nearby. The green peas are hauled to a cannery immediately after coming from the viners. Some farmers are raising peas on the same land each year, but because of the danger of weevil infestation this practice is not recommended. Pea vines are usually sold and used in connection with feeding livestock. Potatoes are planted in May or June and dug late in September or in October.

Plowing for potatoes or peas is usually done during the spring months. Leaving grain stubble on the land over winter allows its use for pasture during that period, and at the same time the stubble serves to hold snow on the field, to conserve moisture, and to prevent erosion by both wind and water. Cultivation is not difficult if done while the soil is moderately moist, but considerably more power is required to plow and cultivate this soil than for any of the lighter textured soils.

Thatuna silty clay loam, poorly drained phase.—The poorly drained phase of Thatuna silty clay loam is a mapping unit used to designate areas of imperfectly and poorly drained soils associated with the soils of the Thatuna and Helmer series. It does not have uniform consistent soil characteristics. The drainage conditions in the different areas are very different, and as a result there are differences in texture, color, and quantity of organic matter in the surface soil and in the quantity of clay and degree of mottling in the subsoil. Several bodies are in the vicinity of Basket Mountain School; one is east of Firwood School; several are about 2 to 3½ miles southeast of Weston Mountain School; and 3 are about 1½ miles southeast of Fairview School. A total of 0.9 square mile is mapped

The surface is smooth and the slopes are generally less than 5 percent. The soil usually occurs in slight depressions or below higher lying lands that serve as a source of water that later appears as seepage in this soil. The surface soil is dark-brown to brownish-black friable granular silty clay loam or clay to a depth of about 10 inches. Beneath this is a 10-inch subsurface layer of weak-brown friable granular silty clay loam, or in some places silty clay. Underlying this is a definite layer of very pale-brown or yellowish-gray ashy material that has a high content of very fine sand. This material is firm when dry but may be crushed in the hand to a fine ashy powder. Immediately below this layer is a pale-brown tough clay that continues to a depth of 6 feet or more. The clay is highly mottled with gray and rusty-brown stains, and on the surfaces of the irregular-shaped blocky aggregates are dark-brown colloidal humus stains. The surface layers are slightly acid, and those of the subsoil are slightly or moderately acid. Plant roots are numerous in the layers above the very pale-brown ashy material, but very few roots occur in the clay subsoil. Though the clay is tenacious and slightly compact, it is not impenetrable to roots. The absence of root growth is probably due to the poor drainage and cold condition.

A large part of this soil has been cultivated, although more than half is now used for pasture. The wetter parts provide good green summer pasturage. The rest of the acreage is used principally for growing wheat, oats, and potatoes. Wheat yields 15 to 20 bushels an acre, with an average of 18 bushels, oats about 40 bushels, and potatoes about 100 bushels.

Areas totaling about 100 acres occur in association with Helmer silt loam. The principal body of about 50 acres is in the vicinity of Little Meadows. External drainage is very poor, and internal drainage is inadequate. The vegetation includes several sedges, timothy, alsike clover, some foxtail, and other water-loving grasses and weeds. Timothy hay has been raised at Little Meadows, but the remaining areas are used principally for pasture, as they remain green throughout the summer season and are highly valued for such use.

At Little Meadows the surface soil to a depth of 2 inches is brownish-gray to light brownish-gray slightly granular friable silt loam. Under native grass cover this layer is matted with grass roots. The dark color indicates an appreciable quantity of humus. Below this and to a depth of about 12 inches there is light brownish-gray firm but friable slightly granular silt loam. Grass roots are not so numerous, and the color is not quite so dark as in the 2-inch surface layer. When moist these two upper layers are dark brown to brownish black. Between 12 and 26 inches is a structureless very pale-brown to yellowish-white ashy very fine sandy loam with a few rusty stains and soft concretionary material, presumably iron. This very pale-brown material is almost devoid of humus and organic matter. Below this is yellowish-gray heavy silty clay loam that contains many rusty-brown stains and some black concretionary material. Although this layer appears massive, it is not cemented but is easily cut with a shovel. When the particles are mashed in the hand they become ashy and powdery. At an average depth of 38 inches this layer is underlain by light silty clay loam material of a similar yellowish-gray color, but because of numerous rusty-brown and black stains and concretions it has a very highly mottled appearance and when crushed appears to be more of a pale-brown color. This layer, though probably higher in some of the mineral plant nutrients than the very pale-brown to yellowish-white ashy layer, contains almost no plant roots or organic residues. This material extends to a depth of about 54 inches, where it merges with material that is of very similar texture and structure but has a much higher content of rusty-brown iron stains and soft concretions.

The few small bodies comprising the rest of this principal variation are in the mountainous section east and southeast of Weston, where most of them occupy comparatively narrow and troughlike basins. The soil profile development is not so pronounced, the surface soil is not so dark, and the mottled layers of the subsoil are usually heavy silty clay loam or silty clay.

LIGHT-COLORED SOILS OF THE BLUE MOUNTAINS

The light-colored soils of the Blue Mountains—the Helmer and Couse series—which occupy high plateau tops, have developed under a forest cover, comparatively high rainfall, and low temperature. They are medium to very light in color, low in organic matter, acid in reaction, and have a fluffy or floury consistence. The subsoils generally contain a distinct light-gray ashy layer immediately overlying heavy-textured, tough, mottled material. Apparently the surface soil and the upper part of the subsoil are largely developed from loess, and the lower part of the subsoil material is residual from the underlying basaltic bedrock.

The soils of the Helmer series are light yellowish brown and have developed under a dense forest of fir, spruce, and tamarack. Those of the Couse series are pale brown or brownish gray and have developed under a comparatively open stand of western yellow pine. Except for the difference in color and organic content of the surface soil, the soils of these two series are very similar.

The Helmer soils are mostly covered by timber and are probably best suited to timber production, although oats, timothy, red clover, potatoes, and berries are grown with fairly good results. The Couse soils are somewhat more productive and better suited to cultivation.

Helmer silt loam.—This soil occurs in the mountainous districts of the northeastern part of the Umatilla area, where it occupies the smooth gently sloping ridge tops and small areas of steep hill slopes. Most of the land is not too steep for cultivation though there are several small areas of only a few acres that are unusually steep or rough. This condition is most prevalent on Blalock Mountain, where several square miles are without roads and accessibility is difficult. A total area of 29.1 square miles is mapped. Most of the bodies are comparatively large, although several comprise less than 80 acres each.

The material from which the soil has developed is mainly of windborne origin, though it is possible that the heavier material of the subsoil has developed from disintegrated and decomposed products of the underlying basaltic rock. Both external and internal drainage are good, but the latter is somewhat restricted at a depth of 2 or 3 feet. The native vegetation consists principally of fir, tamarack, and spruce (pl. 8, *A*), with some huckleberry or tall grasses in the less densely timbered places.

In forested areas the topmost ½-inch layer of forest litter consists of needles and a few very small twigs (pl. 8, *B*). Some of this material is weak brown, and some is dark brown. Below the loose litter is a ½-inch weak-brown to dusky-brown layer of partly decomposed needles. Immediately underlying this is a pale-brown ashy silt loam layer $\frac{1}{16}$- to ⅛-inch thick that appears like a podzolized layer from which iron and aluminum have been leached, leaving siliceous material, though the relatively high pH seems to indicate that it may be a true ash produced by the burning of forest litter. Below this is a light yellowish-brown fluffy or floury silt loam that is moderate brown when moist. This layer is 7 or 8 inches thick and forms the surface of cleared or plowed fields. Between depths of 8 and 18 inches the soil material differs only in being very slightly lighter yellowish brown, possibly indicating a smaller content of organic matter. The next layer is yellowish-white floury or ashy silt loam that contains considerable very fine sand and only about 4 percent of clay. Its thickness varies from a gray film in some places to as much as 20 inches or more in others, averaging about 10 inches. This is a second layer that has been strongly leached, probably by water that has been held up temporarily by the underlying heavier material following periods of heavy rain or melting snow. This ashy material is very low in humus and in most plant nutrients other than potassium. Below the ashy layer is very pale-brown firm but friable heavy silt loam somewhat mottled with gray, which in some places continues to a depth of 40 inches or more but is generally very thin. It is underlain by yellowish-brown heavy silty clay loam or clay that is highly mottled with gray and rusty brown and continues to depths of 6 feet or more or to bedrock. In several places where bedrock is less than 15 feet below the surface the heavy subsoil or substratum continues to bedrock without any apparent change except for occasional angular or rounded basaltic rock fragments, some of which are soft and largely decomposed. These fragments become more numerous with depth, and in some places the topmost 1- or 2-inch layer of bedrock is partly decomposed and may be penetrated with a soil auger. The heavy subsoil is brown to dark brown when moist.

The surface soil is slightly acid, and the lower layers usually become increasingly so. The water-holding capacity is favorable for crop production, and the clay subsoil holds much water that may be obtained by plants. Almost all the moisture held in the lighter textured upper layers is easily available to plant roots, and each of the layers except the yellowish-white ashy one has a good water-holding capacity.

The principal variation in this soil is in depth to bedrock. In many excavations and cut banks, basaltic bedrock is exposed more than 12 feet below the surface, although in other places it is less than 4 feet. Because of the dense cover of timber it was not feasible to outline the shallower areas on the soil map.

Probably the best general use of this soil is for the production of timber, to which it is well adapted by climatic and soil conditions. New stands of timber thrive on cut-over lands if efforts are made to protect the young trees. Most of the older and larger trees have been cut from the more easily accessible areas, and at present the second-growth timber, much of which is more than 1 foot in diameter, is being cut for fuel. Some of the larger timber is cut for the same purpose, and part is used for the manufacture of lumber by sawmills at Milton and Weston and in the mountainous districts east of these towns. In some districts where the trees are 50 to 80 feet high and many of them 12 to 18 inches in diameter, as much as 5,000 board feet of lumber or 10 cords of wood may be cut from an acre. Other areas where the timber is much smaller or less dense yield not more than 2,000 board feet, or 4 cords. Areas in second-growth timber vary widely in the number of board feet to the acre.

Of about 500 acres of Helmer silt loam that have been cleared of timber and stumps, about half is in pasture and the rest is cultivated. The pastures produce timothy, bluegrass, orchard grass, and white clover.

The number of crops that may be grown on cultivated areas is limited by conditions of climate and soil. Oats or timothy are raised for hay, as also is red clover on small areas. Potatoes are grown and marketed principally for seed. Strawberries, raspberries, and blackberries are well adapted and occupy areas that range in size from fractions of an acre to as much as 5 acres. This soil is comparatively low in humus and nitrogen, and, although the chemical analysis of a virgin sample shows favorable quantities of phosphoric acid, it does not produce satisfactory yields of grain over a period of even a few years. Plowing and seeding are usually done in spring. Oats, timothy, and clover for hay yield about 1½ tons an acre. Potatoes average about 70 bushels, strawberries about 1,500 pounds, raspberries about 2,000 pounds, and blackberries or blackcap berries about 2,500 pounds an acre. Berries of all kinds mature so much later than in the valleys and in the lower lying lands that the local markets use all that are produced. Occasionally when very low temperatures occur entire fields of strawberries are killed. Although wheat has been raised on new land, acre yields of 10 to 20 bushels are produced only the first few years, the yields being much less after continuous cropping.

When timber is cut, the beneficial effects of shade and of a surface mulch of needles and twigs that aid in the conservation of moisture are lost. The first year or two after clearing, the soil is subjected to some erosion by water but generally a grass cover soon develops and protects the land from prolonged periods of erosion. Cultivated fields also are subject to erosion both by runoff and by soil blowing. Because of the small extent of the fields, the comparatively gentle slopes, and the protection afforded from winds by the surrounding forest, the effects of runoff and of soil blowing are not so severe as on the Palouse, Waha, Athena, Walla Walla, and Ritzville series. A rotation of red clover for 2 years followed by potatoes and then by oats or timothy hay will help to conserve the productivity of this soil. Whether it is advisable to use Helmer silt loam for cropping purposes depends largely on the soil pattern and economy on individual farms.

Couse silt loam.—This soil represents a gradational condition between the relatively dark-colored soils of the foothills and lower mountains (the Palouse, Waha, and Thatuna series) and the relatively light-colored soils of the Blue Mountains (the Helmer series). The areas lie principally in the mountainous districts east, northeast, and southeast of Weston, although some are southeast of Pendleton and others are within a few miles of Little Meadows. The total area is 8.8 square miles.

Because Couse silt loam represents a transition from grassland to forest, the density of the native vegetation varies considerably from area to area, but in general it consists of an open stand of western yellow pine and tamarack. The openings have a cover of bunchgrasses and some buckbrush.

The relief ranges from smooth to rolling or hilly, but the greater part of the acreage occurs on gently to moderately sloping ridge tops and side slopes. The slopes range from 5 to 15 percent, and almost all areas are smooth enough to be cultivated. External drainage is good and may be excessive on certain of the steeper cultivated slopes. Internal drainage is somewhat retarded by the comparatively heavy and compact subsoils. The parent soil material is mainly loess, but fragments of basalt are present, and in places, especially where the soil is shallow, it appears that the underlying heavier layers are developed essentially from basalt.

In a typical forested area the first inch of soil consists of a brown or dark-brown layer of pine needles and fibrous grass roots, below which to a depth of about 5 inches is weak-brown to pale-brown friable silt loam. From a depth of 5 to 12 inches is a similar-colored layer of slightly firmer consistence that breaks into irregular-shaped coarse crumbs and small clods if disturbed when dry. This is underlain to a depth of about 22 inches by a pale-brown thinly laminated or platy slightly compact silt loam or silty clay loam that upon drying breaks into small clods similar to those of the layer above. The next layer is very pale-brown soft friable loam of fine granular structure 1 to 5 inches thick and somewhat similar in appearance and character to the pale-brown or yellowish-white leached layer in the subsoil of the Helmer silt loam. This rests abruptly on a mottled gray and brown very compact clay layer 3 to 5 feet deep that breaks out of banks into irregular blocks or coarse prisms that are 6 to 10 inches in diameter and are coated with iron-stained colloids. When crushed the material has a pale-brown color. This layer is slowly pervious to water. In some places it rests directly upon underlying fragmentary basalt, from which in others it is separated by a very pale brown mellow silt loam or silty clay loam.

A number of different soils that vary in minor features of the profile have been included in the Umatilla area under the designation of Couse silt loam. These variations cover only small areas and emphasize the transitional nature of the series. They differ in the depth to the underlying basalt, in the depth to the compact layer, and in the color of the various layers. The surface soils of some of the smaller areas are both lighter and darker brown than the soil described.

Probably about one-fourth of Couse silt loam is in pine forest, an equal part is in pasture, and the rest is used for cultivated crops. Wheat, potatoes, peas, oats for hay, red clover, garden vegetables, and berries are the principal crops. Wheat is produced primarily on the lower areas and on those nearer the Thatuna and Palouse soils. Fall-seeded Federation wheat is the principal variety and, with summer fallow, yields about 35 bushels an acre. On the higher lying areas where the soil is lighter colored, some wheat is grown in rotation with clover and potatoes and yields about 18 bushels. Potatoes yield 50 to 150 bushels, depending upon location and management. Peas do well and produce 2,000 to 2,500 pounds. Oat hay and red clover each yield about 1½ tons. A few acres of crested wheatgrass seed have been grown, and yields of about 400 pounds were obtained. Vegetables and berries do well. Timothy, clover, and bluegrass are the main pasture grasses.

On the higher areas, plowing and planting is done largely in spring, but where wheat is the principal crop, seeding is done in fall. On the latter areas, erosion may be serious during periods of heavy runoff, especially early in spring, when part of the soil may still be frozen. Soil blowing may also be significant during periods when the surface is bare.

LIGHT-COLORED SANDY SOILS OF THE COLUMBIA RIVER TERRACES

The light-colored sandy soils of the Columbia River terraces—the Quincy, Ephrata, Rupert, and Winchester series—occupy a large area in the northwestern corner of Umatilla County in which the climate is very dry and the native vegetation consists largely of desert shrubs with a scant growth of bunchgrass in places and annual grasses and weeds on cleared areas. All these soils have developed from old water-laid and wind-laid or wind-modified materials, on the Columbia River terraces. All have sandy surface soils, and most of them have porous sandy or gravelly subsoils and substrata, though in the Quincy series the subsoils are fine-textured and some areas of the Quincy and Ephrata soils are underlain by basaltic bedrock or by consolidated old alluvial material.

The Quincy soils lie at the outer or upper edge of the Columbia River terraces and apparently have developed partly from wind-laid materials; the surface soils are loose and sandy and subject to shifting by the wind, whereas the subsoils are fine and very limy and resemble loess, although in places they appear to be somewhat stratified. The Ephrata soils are porous and sandy and typically lie over beds of gravel cemented by lime in the upper part. The Rupert soils are coarser in texture than the Ephrata, generally are underlain by coarse or gravelly sand, and in most places contain little or no lime within 3 or 4 feet of the surface. The Winchester soils consist of loose wind-shifted sand.

These soils have little or no value for dry farming. In irrigated areas near Hermiston and Umatilla the Ephrata soils are fairly productive, although they must be irrigated frequently. Quincy soils could be farmed successfully if water for irrigation could be supplied at a reasonable cost. The Rupert and Winchester soils are excessively sandy and porous and for the most part are unsuited to cultivation, although small areas of the Rupert soils are farmed.

Quincy loamy fine sand.—This soil occurs most extensively northeast, east, and southeast of Cold Springs Reservoir and southwest of Echo. Small bodies are more widespread throughout the northwestern part of the county. The total area mapped is 25.9 square miles. The surface is smooth or slightly hummocky to billowy and somewhat rolling. The hummocks are 1 to 2 feet in diameter and about 6 inches high, whereas the tops of ridges range from 10 to 20 feet above the lower parts of the valleylike depressions. In many places about four ridges and four or five depressions occur in a mile.

Typically the soil has been formed from wind-laid deposits, although the subsoil materials may be partly water-laid. The native vegetation under which the soil developed consisted principally of bunchgrasses, but because of cultivation in some places and overgrazing in others most of the bunchgrass has been replaced by downy bromegrass, rabbitbrush, sagebrush, mustard, and a number of weeds that provide some grazing in spring. Russian-thistle grows along roads and in other places where much of the surface soil has been removed by wind. A few drainageways that carry water only during periods of exceptionally heavy runoff have been established in certain tracts, but generally the soil absorbs moisture as fast as it falls. In most places there are no obstructions to the percolation of water for many feet below the surface.

The 8-inch surface layer is pale-brown noncalareous loamy fine sand of moderate or low content of humus. The structure is very fine granular to single grain, and the consistence is friable to loose. Beneath this and continuing to 19 inches the material is a very slightly lighter shade of pale brown and probably contains less organic matter than the surface layer. The texture is a heavy loamy fine sand or a light fine sandy loam. The structure is very fine granular to single grain, and the consistence is loose to friable. The material is noncalcareous and is underlain to a depth of about 28 inches by very pale-brown mellow to loose mildly calcareous fine sandy loam. Between 28 and 66 inches is a light very pale-brown highly calcareous fine sandy loam or loam that is weakly held together by lime carbonate. The carbonate is rather thoroughly mixed with the soil, but there are a few soft lime carbonate nodules. Below 66 inches the soil material is similar in color and texture and slightly compact, but it contains less lime and is not so firm as the material above 66 inches.

Below a depth of 24 inches and continuing throughout the rest of the profile in the bodies southwest of Echo are scattered pieces of well-rounded water-worn gravel that range from 1 inch to as much as 4 inches in diameter. The presence of this gravel indicates that the lower part of the soil material was deposited by water.

The entire soil is friable or loose and is easily penetrated by plant roots. It absorbs water rapidly but has low water-holding capacity. The surface soil is almost neutral, but the lower layers are alkaline.

A few areas south of the reservoir on McKay Creek and a few other bodies near Holdman are cultivated. The total area cultivated, however, is less than 200 acres, and yields of wheat average less than 10 bushels an acre. Sheep are grazed during the winter and spring months, and measures for increasing the carrying capacity include restrictions to prevent overgrazing and the establishment of better grasses. At present about 45 or 50 acres are necessary for one animal unit. This soil, if left bare, is subject to serious blowing.

Quincy loamy fine sand, wind-eroded phase.—This phase includes areas that have been or are being modified appreciably by the action of wind. The texture may range from fine sand to very fine sandy loam. The surface soil has been blown away, and in places the subsoil also, leaving grass- or brush-covered pillars standing 12 inches to as much as 3 feet above the blown-out places. In other places fine sand has been deposited in hummocks ½ to 3 feet high. A total of 2.8 square miles is mapped. Several bodies are within a radius of 5 to 10 miles east and southeast of Cold Springs Reservoir, and several others are between 2 and 7 miles southwest of Echo. There is one area in secs. 16, 20, and 21, T. 6 N., R. 32 E., and a small area near the southeast corner of sec. 34, T. 6 N., R. 31 E.

The parent material probably was largely deposited by the wind, although some of it may have been water-laid. The former sparse stand of grasses was killed by clean cultivation in some places and by overgrazing in others, and the unprotected surface has started to blow. Almost no drainage courses have been established, as moisture is absorbed almost as rapidly as it falls. The soil is loose and easily penetrated by moisture and plant roots, although the limy subsoil, exposed in spots, has a firm consistence. The content of humus is very low, the water-holding capacity is poor, and evaporation of moisture from the soil is comparatively rapid.

The surface soil is a pale-brown loamy fine sand of very fine granular structure where covered with grass, but it is loose and single-grained where drifted. Below an average depth of about 20 inches and continuing to about 30 inches is pale-brown loose to moderately firm noncalcareous fine or very fine sandy loam. Between 30 inches and 6 feet or more is very pale-brown moderately or highly calcareous firm fine or very fine sandy loam. The lighter color of this lower layer is due to the uniform distribution of powdery particles of lime carbonate through the soil. Usually the carbonate of lime is somewhat concentrated between 3 and 4½ feet below the surface, although below a depth of 5 feet the material continues to be very pale brown and is moderately to highly calcareous. The noncalcareous surface materials are almost neutral, and the lower layers are alkaline.

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In some of the bodies southwest of Echo, at a depth of 3½ to 4½ feet, there is a stratum of water-worn gravel firmly cemented by lime carbonate. The gravelly stratum extends to 6 feet or more below the surface.

Largely because of unsatisfactory moisture conditions and great susceptibility to wind erosion, none of the soil is cultivated and less than half is of much value for grazing. In the areas that have a partial cover of grasses, weeds, and brush, 60 to 100 acres are required for one animal unit. The rest of the soil, which has practically no value in its present condition, should be fenced to stop all grazing. Grasses and plants that are adapted to the soil should be planted in order to reclaim it and eliminate potential blow spots.

Quincy loamy fine sand, shallow phase.—This phase, of which 2.3 square miles is mapped, is not typical of the Quincy soils, because of the underlying gravel or basalt that generally occurs at a depth of less than 3 feet. It occurs in several bodies a few miles southwest of Echo and in others west of Butter Creek. Much of the surface is marked by small hummocks about 6 inches high and 12 to 18 inches in diameter. Ridges about 10 or 12 feet high with intervening depressions or valleys are also characteristic. Most of this soil is underlain by either water-laid sediments or basaltic bedrock, although the typical Quincy soils are developed largely from wind-laid materials. Only a few incipient drainage courses have been eroded, as moisture from rain is usually absorbed as rapidly as it falls. Vegetation includes small stands of bunchgrass together with a moderate to sparse growth of downy bromegrass, rabbitbrush, sagebrush, mustard, and several weeds.

The upper 6 or 8 inches is pale-brown loose noncalcareous loamy fine sand low in organic matter. Below this and to a depth of about 15 inches the soil is similar to the surface soil except that it is a shade lighter and contains slightly less organic matter. This is underlain by a mildly or moderately calcareous very pale-brown incoherent fine sandy loam or loamy fine sand that continues to an average depth of 25 inches, where it grades into soil similar in texture but somewhat firmer, still lighter in color, and highly calcareous. In some places it is very softly cemented by carbonate of lime. This layer is underlain by basaltic bedrock in some places and by lime-cemented gravelly material in others. The depth of the soil above gravel or rock ranges from 18 inches to 3 feet. Scattered pieces of water-worn gravel are in both surface soil and subsoil.

This shallow phase is not cultivated but is used principally for grazing sheep during the winter and spring months. The number of animals grazed should be restricted to prevent overgrazing. In places soil blowing, especially during the spring months, is serious.

Quincy fine sand.—The 17.2 square miles mapped is chiefly near and a few miles east, northeast, and southeast of Cold Springs Reservoir and southwest of Echo. In general the surface is relatively smooth, except that slightly rolling or ridgy areas and hummocks have been formed by blowing and by the accumulation of sandy materials. The ridges are more generally distributed, whereas the hummocks, which are about 6 inches high and 15 inches in diameter, are more spotted in their occurrence. The ridges generally are only a few feet higher and the depressions a few feet lower than the average level of the gently sloping surface. The soil has developed from wind-laid materials, except in some bodies southwest of Echo, where the subsoil includes scattered water-worn gravel. Bunchgrasses apparently formed the principal vegetative cover while this soil was developing, but it is evident that the stand was sparse or the growth attained was comparatively small, as the content of organic matter in the soil is low. The present vegetation, except for limited areas of bunchgrass, consists principally of downy bromegrass, rabbitbrush, sagebrush, Russian-thistle, mustard, and a number of weeds.

The 8-inch surface layer is weak brown to pale brown and has somewhat of a salt-and-pepper appearance. The soil is loose noncalcareous fine sand in which there are a few fine grass roots. Beneath this layer and continuing to a depth of 30 to 46 inches the material is very similar, though it is more nearly pale brown and contains slightly less organic matter. This layer is underlain by very pale-brown loose mildly calcareous fine sand with which there is a small percentage of very fine sand. At a depth of about 60 inches it grades into very pale-brown moderately to highly calcareous loose loamy fine sand, which continues to 80 inches or more below the surface, where it is underlain by moderately calcareous material of similar appearance. In some places the calcareous material is not so deep as described and the zone of high lime accumulation occurs between 4 and 6 feet below the surface. The entire profile is low in organic matter and light in texture, although when slightly moist the soil will stand in a vertical cut without very much caving.

To a depth of 6 or 8 inches the surface soil is practically neutral, but the layers below are alkaline. Where the soil is covered with grasses and brush, tiny plant roots penetrate deeper than 6 feet below the surface. In most of the area in sec. 25, T. 3 N., R. 28 E., and in a few other places southwest of Echo the depth to rock is less than 36 inches.

Some areas are used for growing wheat, which generally yields less than 10 bushels an acre. Higher yields are obtained on the slopes of some hills, where seepage water is beneficial, and on about 800 acres in several bodies in the vicinity of Holdman, where this soil occurs in association with heavier and more productive soils. Generally, however, the soil is too much subject to blowing and has too low moisture-holding capacity to be suitable for production of crops. Most of Quincy fine sand is used for grazing sheep during the winter and spring months. About 45 or 50 acres are necessary for one animal unit. The carrying capacity could be increased by better practices of range management. There is need to practice restrictive grazing and to retard soil blowing.

Quincy fine sand, hummocky phase.—This phase is essentially the same as the typical soil except that the surface soil is still looser and has been shifted even more by wind. A large number of hummocks and low dunelike ridges form prominent topographic features. The hummocks or ridges range from 8 inches to more than 4 feet in height and from 18 inches to 6 feet or more in diameter. In places the hummocks or ridges are several yards in length and lie parallel to the prevailing direction of the wind.

The phase occupies several areas a few miles east and southeast of Cold Springs Reservoir. It has been derived from wind-laid materials, and its features are those characteristic of a soil that has developed from excessively drained materials in a section of grassland where the annual rainfall averages less than 10 inches. Drainage courses are not important, as most of the moisture is absorbed by the soil as rapidly as it falls. The soil supports a sparse stand of downy bromegrass, some bunchgrass, rabbitbrush, sagebrush, Russian-thistle, mustard, and several less common weeds. A total area of 2.1 square miles is mapped.

The entire soil is loose and readily penetrated by plant roots and moisture. The first few inches of the surface layer are practically neutral, and the lower layers alkaline. The 6- or 8-inch surface layer is weak to pale brown and low in organic matter. A subsurface layer that extends to a depth of about 30 inches is slightly lighter in color and lower in organic matter. Both layers are noncalcareous. Between depths of 30 inches and 6 feet or more, the soil is very pale-brown mildly or moderately calcareous fine sand or loamy fine sand.

Sheep graze on this soil in spring, when the plants are green and tender. About 50 or 65 acres are required for one animal unit. The carrying capacity of the range could be improved by controlled grazing. This soil is too loose and too subject to wind drifting to be suitable for cultivation. Under irrigation, internal drainage would be excessive and large quantities of water would be necessary to produce crops.

Ephrata fine sandy loam.—This soil is developed from old alluvial sediments that have been somewhat modified in places by wind-laid or wind-shifted materials. The most extensive bodies are about 2 miles northeast of Stanfield, but several bodies are southwest of Echo and one body occurs about half a mile northwest of Stanfield. The total area mapped is 5.3 square miles. The surface is generally gently sloping, though a few small hummocks and a few breaks in the general smooth slope of the land are common in virgin areas. The soil is naturally porous and excessively drained because of the loose and coarse-textured underlying materials. In the virgin areas the principal vegetation consists of downy bromegrass, sagebrush, rabbitbrush, Russian-thistle, mustard, tarweed, and some sandbur and bunchgrass. Natural drainage channels are absent or very rare as the soil absorbs rain water very quickly.

The upper 8 inches is pale-brown noncalcareous loose fine sandy loam of moderate or low content of organic matter. Between 8 and 32 inches is slightly lighter pale-brown loose noncalareous loamy fine sand low in organic matter. This layer is underlain by very pale-brown loose loamy fine sand, mildly calcareous and very low in organic matter. At an average depth of 42 inches and continuing to about 51 inches is a very pale-brown layer of rather firmly cemented gravel and sand, the cementing material of which is principally calcium carbonate. In some places this layer is only weakly or moderately cemented, whereas in others it is difficult to break with an iron bar. The cemented gravel and sand are everywhere permeable to water, but in places are so hard and dense that they are not penetrated by most plant roots. The parent material below consists of light brownish-gray loose mildly calcareous gravel or gravelly sand. In some places below 5½ or 6 feet the percentage of gravel is very low and a mixture of black basaltic and white quartz sand, similar to that underlying soils of Rupert series, characterizes the substrata. At variable depths below 6 feet is a substratum of basaltic bedrock. The surface soil is slightly alkaline, and the lower layers are slightly or moderately alkaline.

About 1,000 acres have been leveled and are irrigated. Alfalfa is the principal crop, with corn for grain, corn for fodder, and potatoes ranking in acreage in the order named. About 350 acres of the irrigated land is used only for pasture. The pasture land does not receive intensive irrigation like the land for other crops, but it is flooded occasionally or is in low places where it receives natural seepage or waste water from higher lying irrigated land. Alfalfa yields about 3 tons an acre; potatoes, about 140 bushels; and corn for grain, about 30 bushels, and for fodder, about 7 tons. The carrying capacity of irrigated pasture varies considerably with the kind of grass—bluegrass, clover, or saltgrass—and with the quantity of water received by the land. From 2 to 4 acres of permanently moist saltgrass pasture is required for an animal unit, but 1 acre of a good stand of bluegrass pasture that is irrigated throughout most of the year will more than keep one cow for a period of about 9 months.

The native plants afford some forage for sheep in winter and especially in spring until about May 1, when the growth of grasses and weeds is slow and the grasses become tough and dry. About this time the grasses in the higher lying districts are favorable for grazing, and the sheep are driven to the mountains. Approximately 50 acres are required to support one animal unit. The range could be greatly improved by exercising care to prevent overgrazing.

In a few low-lying irrigated areas there is insufficient natural outlet for underground water, which consequently has risen to within a few feet of the surface. This condition has given rise to the accumulation of salts at or near the surface in a few bodies northeast of Stanfield. To correct this condition, a ditch has been constructed there through parts of this soil. If it keeps the water table 5 feet or more below the surface, the salts may be leached out by flooding the land so that the water will percolate through, dissolve the salts, and carry them out in the drainage water.

Ephrata loamy sand.—This loamy sand occurs in the area between Hermiston, Stanfield, and Cold Springs Reservoir, and many other bodies are west of Echo and southwest of Umatilla. The total area is 29.7 square miles. The surface is rather variable, as it is smooth in places and hummocky and somewhat broken in others. The hummocks are about 5 inches high and 12 inches in diameter. The ridges or occasional breaks in the slope range from 18 inches to as much as 3 feet in height.

Although the materials from which it is developed are principally old alluvial deposits, the first few inches of the soil probably contain appreciable quantities of wind-laid sands. In the deeper substrata are many water-worn stones and boulders that apparently have been carried by fast-flowing water (pl. 5, *B*). The gravel and stone are from basalt, granite, conglomerate, and other rocks. Drainage channels have not been established, because all moisture is absorbed as rapidly as received. Internal drainage is excessive, except in a few places where cemented gravelly layers occur. The retardation of the downward movement of irrigation water or seepage from canals gives rise to wet and salty conditions in a few small areas south and east of Hermiston.

The natural vegetation consists of sagebrush, some bitterbrush, rabbitbrush, Russian-thistle, mustard, tarweed, and some downy bromegrass.

The surface soil to a depth of about 21 inches is pale-brown loose single-grained noncalcareous loamy sand, low in organic matter. Between depths of 21 and 35 inches the soil is not quite so loamy, is lower in organic matter, and is lighter in color. Below a depth of 35 inches and continuing to 40 inches the material is even less loamy, contains almost no organic matter, is moderately or highly calcareous, and is very pale brown. All these layers are loose and porous. In most places beds of gravel or gravelly sand occur below a depth of about 40 inches. The deeper substrata consist of gravel and boulders with variable admixtures of sand. In a few places the gravel lies more than 6 feet below the surface and the subsoil there is medium to coarse sand. In some places basaltic bedrock occurs about 6 feet below the surface, but in others as much as 40 feet or more. The surface soil of virgin areas is alkaline, and the subsoil is slightly or highly alkaline. Grass and plant roots are numerous in the surface soil, and a few fine roots extend downward to 6 feet or more, depending upon the texture and the depth to which moisture usually penetrates.

About 2,000 acres in the vicinity of Cold Springs Reservoir differ slightly in that the subsoil material is a finer sand. The other features and characteristics are similar to the typical soil.

About 500 acres of irrigated land are used for growing alfalfa, 200 acres are in corn for grain, 100 acres in corn for fodder, 30 acres in potatoes, 30 acres are used for growing melons, 20 acres are in squash, and about 50 acres are planted to apple orchards. Most of the crops are irrigated once every 2 weeks during the summer months, and the average use for the season for all crops is about 5 acre-feet. More water is used for alfalfa and fruit, and less for corn, potatoes, and squash. Yields of alfalfa average almost 3 tons an acre; corn for grain, about 30 bushels, and for fodder, about 6½ tons; and of potatoes, about 120 bushels. Virgin areas are used only for grazing. Because of the type of vegetation and the very low rainfall about 40 acres are necessary for one animal unit.

Ephrata loamy sand, poorly drained phase.—Prior to the development of irrigation the characteristics of this phase were similar to those of the typical soil. Because of the position of areas of this soil below canals or in depressions below extensively irrigated areas or because basalt bedrock, cemented gravel, or other impervious substrata are near the surface in other areas, seepage water has appeared at or near the surface. As a result appreciable quantities of salts have accumulated there following evaporation. In some places small lakes or marshes have been formed in depressions and a high water table is present in surrounding areas.

The soil occupies many widely separated tracts in the irrigated districts near Hermiston, Umatilla, and Stanfield. The total area includes 4.2 square miles. Many bodies are on slopes immediately below canals, where they receive seepage water, but most of them are in comparatively flat places below higher irrigated lands or in troughlike valleys. Although the parent materials are principally sandy water-laid sediments derived from various rocks, they also probably contain admixtures of wind-laid or wind-shifted deposits.

To a depth of about 20 inches the surface soil is pale-brown noncalcareous loose loamy sand with a low content of organic matter. Below this and to a depth of 32 inches the material is similar but slightly lighter in color and almost devoid of organic matter. In places this layer is underlain to a depth of 6 feet or more by very pale-brown loose sand or slightly loamy sand that is moderately to highly calcareous. In many places, however, there is a hard impervious substratum at variable depths of 3 to 6 feet or more below the surface. This layer may consist of basaltic bedrock, cemented gravel, or semiconsolidated finer sediments.

Most of the areas are used only for pasture (pl. 9, *A*), a valuable use, however, in connection with dairying. The bodies a few miles southwest of Stanfield and some of those north of Hermiston where saltgrass comprises the principal cover have high accumulations of salts. Most of the other bodies that are only slightly or not at all affected by salt, support a stand of blueglass, foxtail, strawberry clover, and other grasses and sedges. Tules grow in some marshy places or at the margins of small lakes. The carrying capacity ranges from 2 to 5 acres an animal unit, but it would be less than one-tenth of that if water were not run in the canals or if the irrigation of adjacent lands were abandoned.

The reclamation of this soil would involve a variety of problems in drainage. In many places canals would have to be lined to prevent seepage, and in others both intercepting and outlet drains would be necessary. In the bodies that are between 3 and 5 miles north of Hermiston, impervious or almost impervious basaltic rock underlies the soil and prevents drainage. In these instances the cost of draining would be more than the reclaimed land would repay, even over a long period of years.

Ephrata sand.—This soil occupies 66.7 square miles in the northwestern part of the area. Most of the surface consists of smooth gentle slopes, the uniformity of which is broken by a few low ridges, hummocks, or other irregularities. Considerable leveling is generally necessary when the land is prepared for irrigation. The soil has been developed from sandy sediments that have been more or less shifted by wind. Very few drainage channels have been formed, as moisture is readily absorbed. The water-holding capacity is relatively poor, and drainage is generally excessive. A few small areas underlain by bedrock or hardpan and a few situated on low ground are poorly drained. The entire soil is loose and porous but will stand in a cut bank without much caving. In virgin areas plant roots are distributed sparsely throughout the soil to depths of about 4 feet, or to the depth that moisture penetrates. The principal plants include downy bromegrass, rabbitbrush, sagebrush, mustard, tarweed, and alfileria.

The 8-inch surface layer is loose noncalcareous medium or fine sand of a weak- to pale-brown color. The intermingled dark- and light-colored sand grains give it somewhat of a salt-and-pepper appearance. Between 8 and 36 inches the material is similar, but is slightly lighter in color. Below this is a layer of pale-brown loose noncalcareous medium and coarse sand that becomes coarser with depth. At about 40 inches is a bed of gravel or gravelly sand, generally lime-cemented in the upper few inches. In a few places the material at this depth is sandy rather than gravelly and is calcareous but not cemented. The sand and fine gravelly materials of the subsoil are rounded or subangular and are principally dark-gray or black basalt grains with admixtures of gray or white particles of quartz.

Accumulations of calcium carbonate occur at variable depths between 2 and 5 feet below the surface. It may be present in such small quantities that the material is only mildly or moderately calcareous. In other places it cements the gravel and sand into layers of variable hardness. These layers range from an almost indurated hardpan that is difficult to break with an iron bar to a weakly cemented one that may be easily crumbled in the hand. At depths varying between 6 and 30 feet or more is basaltic bedrock. Under virgin conditions the surface soil is slightly alkaline and the lower layers are slightly or moderately alkaline. In most places coarser sediments, including angular fine gravel and well-rounded gravel 2 inches or more in diameter, occur at depths of 30 inches or more. In other places, principally west and southwest of Stanfield, the subsoil material to a depth of 7 feet or more consists largely of fine sand. Surface layers of fine sand above the gravelly subsoil occur in practically all the areas between the Union Pacific Railroad (Spokane branch) and the Columbia River near Umatilla; in a strip about one-fourth mile wide immediately south of the railroad and extending from a point about half a mile west of Umatilla to about 2½ miles east of that town; and in the large body that extends southward and southwestward from Cold Springs Reservoir to a point about 4 miles north of Echo.

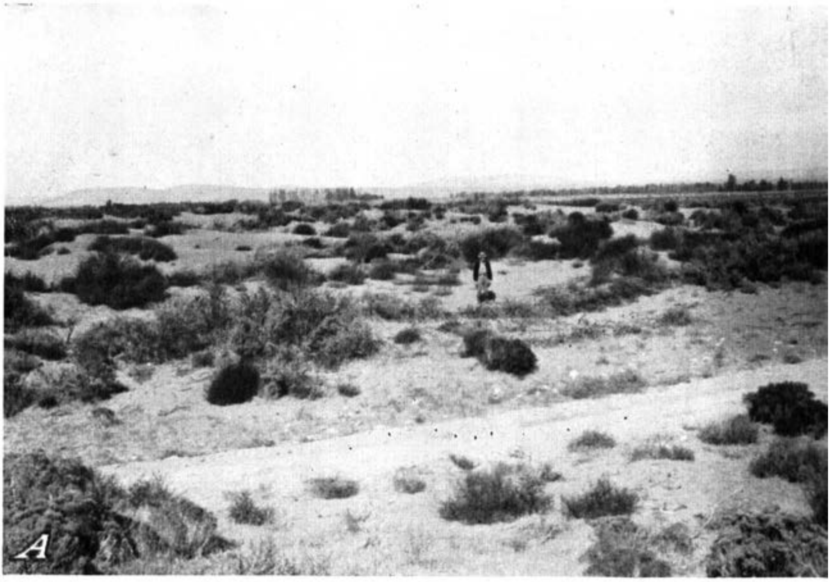
A number of areas with profiles differing slightly from the one described have been included with Ephrata sand. Another variation is in the hummocky areas near Hinkle, particularly to the west. The hummocks vary in size, but as a rule are 1 to 4 feet above the surface, 2 to 5 feet in width, and 3 to 30 feet or more in length. They generally lie parallel to the direction of the prevailing winds.

The variations of Ephrata sand do not appear to be especially significant in respect to the productivity of the areas for native vegetation. Under irrigation, it is probable that the areas underlain by fine sand to a depth of 7 feet or more would require slightly less water.

About 7,000 acres are irrigated. Alfalfa is the most important crop. Bluegrass mixed with thin stands of alfalfa, used for pasture, is probably second in extent of the irrigated crops, and is followed by corn for grain, corn fodder, other hay, including barley cut for hay, watermelons and cantaloups, potatoes, squash, wheat, barley, and asparagus. Other irrigated crops of minor extent are peaches, apricots, artemisia, and garden vegetables, as carrots, onions, and lettuce. Yields of alfalfa range from 1½ to 6 tons and average about 2½ tons an acre; corn for grain yields about 27 bushels and for fodder, 5½ tons; mixed hay, 2 tons; melons, 11 tons; potatoes, 80 to 140 bushels; squash, 7 tons; wheat, 15 to 40 bushels; and barley, 20 to 45 bushels. Peaches and apricots average about 4 boxes to the tree.

The quantity of water used varies, 4 to 9 acre-feet being used on alfalfa and orchard crops, and much less on corn, potatoes, and crops that mature and are harvested in a comparatively shorter season. Most crops are irrigated once each 2 weeks during the irrigation season. For alfalfa, fruit, and several of the other crops, irrigation starts in March and continues until September. If water is available, alfalfa

A, Pasture on Ephrata loamy sand, poorly drained phase, near Hermiston. *B*, View of Rupert coarse sand northeast of Hermiston, formerly irrigated but now abandoned. The finer textured Ephrata soils in the background are irrigated and produce principally alfalfa, pasture, and corn.



A, View of Winchester sand northeast of Hermiston. Barren areas blow and shift with each high wind. Rabbitbrush, bitterbrush, sagebrush, Russian-thistle, and some grasses grow between hummocks of sand. *B*, Area of scabland east of Umatilla, showing typical irregular outcrops of basaltic lava rock with intervening flats or shallow basins occupied by sandy soil material.

is irrigated late in fall or in winter. If the soil is sufficiently moist, less alfalfa is winterkilled.

Much of this soil has never been cultivated and is used only for grazing sheep during the winter and early spring months, when the grasses, weeds, and brush are greenest and are making their greatest growth. Approximately 50 acres are required for one animal unit.

Ephrata sand, shallow phase.—This phase occurs in the northwestern part of the area. The surface is generally gently sloping, though in places it is undulating and in others the soil occupies hilltops, or knobs, or the upper part of comparatively steep slopes. The soil has developed from shallow wind-laid and water-laid deposits overlying relatively impervious basaltic bedrock. The annual rainfall is about 8 inches, and the water is quickly absorbed and used by grasses, weeds, and brush, which constitute the principal vegetative cover. The virgin areas support some downy bromegrass, rabbitbrush, sagebrush, Russian-thistle, and other less conspicuous weeds that afford limited grazing for sheep during the early spring months. Since the installation of irrigation, poor drainage and salt accumulation have developed and are serious in a few places on these areas. The basaltic bedrock does not slope evenly but is somewhat wavy or contains pockets from which water cannot escape by gravity. A total area of 10.4 square miles is mapped.

The 6- to 8-inch surface layer is pale-brown loose noncalcareous fine sand that is low in organic matter. Below this and continuing to an average depth of 28 inches, the soil material is of similar color, structure, texture, and reaction, but is very low in organic matter. This is underlain by very pale-brown mildly or moderately calcareous loose fine sand or loamy fine sand that continues to basaltic bedrock, which occurs at variable depths, from 18 to 40 inches or more, and is usually capped with a layer of gray firmly cemented lime carbonate that ranges in thickness from 1/4 to 1 inch. The soil is slightly or moderately alkaline, Plant roots are usually numerous in the surface soil and may extend to bedrock.

Certain variations from the soil described have been included with this phase. The principal variation, which occupies large areas west of the Umatilla River several miles southwest of Hermiston, is one in which a hardpan layer, occurring at a depth of 18 to 30 inches, consists of sandy and gravelly materials firmly cemented together by silica and calcium carbonate. The thickness of the hardpan varies from 3 to more than 12 inches, and penetration by plant roots or water is very definitely restricted. Below the hardpan layer are loose to weakly cemented highly calcareous gravelly and sandy materials.

About 270 acres of this phase are given surface irrigation and produce alfalfa, potatoes, and corn. About 400 acres that receive seepage water produce bluegrass, foxtail, sweetclover, and other less conspicuous grasses and weeds. Alfalfa yields about 2 tons an acre; potatoes, 85 bushels; and corn for grain, 25 bushels, and for fodder, 5 1/2 tons. The carrying capacity of the irrigated pasture averages about 2 acres per animal unit.

The virgin areas are used only for grazing by sheep during the winter and spring months. Approximately 45 to 50 acres are required for one animal unit. The feed during the winter period is not highly nutritious unless bunchgrass is available. During these months more or less hay is fed, depending upon depth of snow, condition of grass, and condition of the animals. During the spring months grazing is usually very good if there is sufficient rainfall. About May 1 the sheep are usually driven to the mountains. Grazing should be restricted in order to increase the carrying capacity of the soil.

Rupert coarse sand.—This soil occupies extensive areas north and northeast of Hermiston (pl. 9, *B*) and northeast of Cold Springs Reservoir. Other bodies are at the Morrow County line northwest of Hermiston. A total area of 21.8 square miles is mapped. The surface is generally undulating or rolling, although there are many small areas of rather smooth gently sloping land.

The soil has developed from alluvial terrace materials that consist mainly of sand fragments derived from basalt together with an admixture of quartz particles. It is coarse-textured and very porous, and under the prevailing low annual rainfall only sparse stands of grass or brush have been sustained. No drainage channels have been established as moisture is absorbed as rapidly as received. The natural vegetation consists of sparse stands of bitterbrush, sagebrush, rabbitbrush, downy bromegrass, and a few other less conspicuous plants.

The upper 8 inches of this soil is brownish-gray to pale-brown loose or fairly firm slightly loamy coarse sand low in organic matter. Beneath this and continuing to a depth of 21 inches is material that is similar but somewhat lower in organic matter. This layer in turn is underlain by similar material of slightly coarser texture and even lower in organic matter. At an average depth of 38 inches is clean angular or slightly rounded very loose coarse sand and fine gravel that has the appearance of a mixture of salt and pepper because of the dark basalt particles intermixed with white or slightly yellowish quartz particles from which derived. This material continues to bedrock, which is usually more than 6 feet below the surface. The upper layers of this soil are free from calcium carbonate and other more soluble salts. In places calcareous material occurs in seams or spots in the subsoil below 36 inches or is well distributed throughout the soil mass below a depth of about 60 inches. In general this soil has a lower concentration of lime in the subsoil than the Ephrata soils, and it is looser and more porous.

Approximately 200 acres are cultivated and irrigated, the principal crops being alfalfa, corn, and potatoes. Alfalfa yields about 1½ tons an acre; corn, about 20 bushels of grain or 4½ tons of fodder; and potatoes, about 85 bushels. The soil is so porous that much care is necessary to prepare the land for irrigation. Water should be distributed in short runs, and moderate or large heads should be used to obtain efficient and even distribution. Crops on this soil need frequent irrigation. The extra cost of applying water, the large quantity needed, and the comparatively low yields obtained do not justify the expense of any further irrigation development. Many farms that were once irrigated have since been abandoned. The natural forage that grows without irrigation is very limited. Where sheep are grazed, approximately 65 acres are necessary for one animal unit. Turkeys are raised on some of the dry areas north of Hermiston. Considerable soil blowing occurs on areas that have been cleared for cultivation.

Rupert sand.—This soil is formed from sandy alluvial terrace deposits. Fragments and weathered products of basalt are the principal materials, but quartz or granite fragments in which some mica occurs are also present. The soil has developed under arid conditions where the annual rainfall is less than 9 inches and where the native vegetation is a sparse stand or a short growth of grasses, weeds, and shrubs. These plants have contributed a small quantity of organic matter, which is incorporated in the soil and is largely responsible for the brownish color of the surface soil. Many areas are well distributed throughout the northwestern part of the Umatilla area from near Cold Springs Reservoir westward to the Morrow County line, and many bodies are southwest of Echo and west of Butter Creek. The total area is 16.1 square miles. The soil is loose and porous. No drainage channels occur because water percolates rapidly into the soil. The surface is undulating or somewhat rolling or ridged, although many areas contain 2 to 10 acres of gently sloping or almost flat land. Although much of the soil is excessively drained, in some of the areas that occupy depressions, a high water table has resulted from the irrigation of adjacent lands.

The 8-inch surface layer is loose noncalcareous sand of a salt-and-pepper appearance but with a brownish cast. The quantity of organic matter is relatively low. Below 8 inches and to a depth of about 38 inches the material is of similar texture, consistence, and reaction, but the color is slightly less brown, because of a smaller quantity of organic matter. In places this layer consists in part of fine sand or loamy fine sand. Between 38 inches and 6 feet or more is a medium to coarse sand consisting of a mixture of black basaltic and gray, slightly yellowish, or white quartz grains and some flakes of muscovite mica. Probably 65 percent of the total mixture consists of angular or slightly rounded particles of basalt. This lower material is rather clean and practically devoid of organic residue. In places, thin lenses of slightly grayish calcium carbonate may be present at variable depths below 38 inches. Impervious basaltic bedrock generally forms the underlying stratum at 6 feet or more below the surface. In some places as much as 30 feet of unconsolidated sands and gravels overlie the bedrock; in others the subsoils and substrata are characterized by alternating layers of variable texture. Some of the layers are coarser, and others are finer than those of the more typical areas.

Between 1,400 and 1,800 acres are irrigated. The principal crops are alfalfa, pasture grasses, corn for grain and fodder, potatoes, melons, and squash. Alfalfa, if irrigated once in 2 weeks, requires about 8 acre-feet of water each season and produces an average yield of about 2½ to 3 tons an acre. The pasture obtained from grass varies with the quantity of water applied or with the quantity of seepage water, the stand and kind of grass, and the care that has been exercised by the farmer. Corn requires about 4½ acre-feet of water to produce 5½ tons of fodder or 25 bushels of grain. Potato yields range from 75 to 130 bushels an acre, and melons and squash average about 6½ tons. Considerable labor is necessary both in the preparation of land and in the application of irrigation water. Because of the porous character of the soil, large heads and short runs of water are necessary for the most efficient irrigation.

The uncultivated areas support a moderate or sparse stand of bitterbrush, downy bromegrass, sagebrush, rabbitbrush, mustard, Russian-thistle, and a few other early maturing weeds. The land is used to a limited extent for raising turkeys, and nonirrigated areas are used for grazing sheep during the early spring or winter months. Forage is limited, and as much as 60 acres are required for one animal unit. No erosion by water occurs because of the low rainfall and the porosity and coarse texture of the soil, but the surface is shifted somewhat by winds during the summer and fall months. Overgrazed areas blow more than others, and it is probable that most of the areas not now irrigated should be taken entirely out of grazing and seeded to grass in an effort to control drifting.

Winchester sand.—This soil is very loose and too unstable and porous to be of much value for producing crops even under irrigation. The soil occurs rather extensively in the western part of the area, where it is associated with others of coarse texture. Several bodies are north and east of Hermiston, and others are widespread southwest of Echo and east and northeast of Cold Springs Reservoir. The total area mapped is 23.3 square miles.

Most of the sand constituting this soil has blown from nearby alluvial sediments and has been deposited probably where brush or weeds have lessened the velocity of the wind. The surface is irregular and dunelike, with intervening saucer or troughlike depressions between the dunes or ridges. The dunes range from about 3 feet to as much as 12 feet or more in height above the bottoms of the depressions. The topographic features are such as to render leveling or cultivation obviously impracticable. No drainage courses have been established because moisture is absorbed as fast as it falls.

Many bodies are practically barren, and the surface soil is almost constantly shifted about by the wind. Most of the barren areas are located east and northeast of Cold Springs Reservoir, but several are west of Umatilla River and near the Morrow County line.

Although many bodies are practically barren, others support a cover of brush, weeds, and some grasses and are well stabilized. Bitterbrush, a dark-green woody perennial bush that ranges in height from 2 to 6 feet, is quite prominent on the soil near Hermiston. Other plants include sagebrush, Russian-thistle, tarweed, mustard, and downy bromegrass (pl. 10, *A*).

The 8-inch surface layer is a pale-brown or light brownish-gray loose noncalcareous sand, the individual grains of which are either black basalt or gray or white quartz, but there is sufficient organic matter to give this layer a brownish cast. Below 8 inches and to a depth of about 22 inches is loose noncalcareous medium sand that has the appearance of a salt-and-pepper mixture because of the black basalt grains and the gray or white quartz grains. This layer contains less organic matter and is coarser in texture than the surface soil. Beneath this and continuing to about 35 inches is black-and-white loose noncalcareous medium sand with only a slight brownish stain. This material is underlain by black-and-white loose noncalcareous medium and coarse sand that continues to a depth of 6 feet or more below the surface.

The entire soil is so loose that it caves to an angle of almost 45° when a hole is dug. In some of the bodies east and northeast of Cold Springs Reservoir, the entire soil to a depth of 6 feet or more consists of loose black and white noncalcareous sand or fine sand. In other bodies in that section, the uppermost 10 or 12 inches consists of clean black-and-white sands, below which are fine-textured materials very similar in characteristics to the subsoil of Quincy fine sand or Quincy loamy fine sand. Variations in the depth of the surface layer exist from place to place. In a large area about 5 miles north of Holdman, several inextensive bodies of Quincy fine sand have been included with this soil. In a number of areas northeast of Hermiston the surface soil is coarser and contains less organic matter than the more typical Winchester sand. It consists of black-and-white noncalcareous loose medium and coarse sand to a depth of 6 feet or more.

The value of vegetation on Winchester sand for grazing is almost negligible. Where considerable brush is growing, the surface materials are stationary, but in most places, especially where the surface is practically barren, the sand shifts or blows with each wind of high velocity. The dunelike ridges are continually moving in the direction of the prevailing wind and are covering less sandy areas. Grazing on this soil should be terminated, and plants should be established to bind the soil and to protect it from blowing. The grazing value probably would not repay the cost of improvements, but the quantity of dust in the air would be lessened and the soil would not be continually shifting and covering more valuable types.

SOILS OF THE BOTTOM LANDS AND LOW TERRACES

The soils of the bottom lands and low terraces—the Snow, Caldwell, Hermiston, Onyx, Yakima, Stanfield, and Umapine series—have a wide range in characteristics, although all lie on comparatively low, level land and all have developed from alluvial soil materials. The Snow and Onyx soils are deep, friable, and well-drained, lack definite surface soil and subsoil layers, and are typically not calcareous. The Caldwell soils are calcareous, dark-colored, and imperfectly to poorly drained. The Hermiston soils are brownish gray with light-colored limey subsoils. The Stanfield and Umapine soils are light-colored and imperfectly to poorly drained, contain high concentrations of soluble salts, and are very limey, and the Stanfield soils have a layer of lime hardpan in the subsoil. The Yakima soils are shallow and more or less gravelly or stony over porous beds of gravel, cobbles, and boulders.

The Snow, Onyx, and Hermiston soils are productive under both dry farming and irrigation. Some of the better drained less salty areas of the Caldwell, Stanfield, and Umapine soils are productive under irrigation, and the poorer areas are used for pasture. The Yakima soils are used for growing apples, prunes, and tomatoes under irrigation but are hard to work, require large quantities of water, and are practically worthless for dry farming.

Snow silt loam.—This soil occurs mainly in many narrow bodies adjacent to streams in the foothills or mountainous sections and in a few bodies several miles from the mountains on the flood plains of the larger streams. The native vegetation consists principally of grasses, although along stream channels where water is available most of the year, cottonwood and willow trees, brush, and vines are common. Being an alluvial soil, its parent materials have been washed from the dark-colored soils of the uplands. The total area surveyed is 7.4 square miles.

The relief is generally smooth or gently sloping. The gentle slopes have about the same gradient as that of the adjacent stream. Many of the rather narrow bodies that occur parallel to small streams are irregular in outline, and some are cut by small intermittent stream channels. All these irregularities add to the expense of cultivation and harvesting. The annual rainfall ranges from 14 to 30 inches. External and internal drainage are good.

The 8-inch surface layer is brownish-gray friable and granular noncalcareous loam and when moist is brownish black or dusky brown. Between a depth of 8 inches and 5 feet or more the soil material is similar to the surface layer except that it is slightly less dark in color and is slightly lower in organic matter. The entire soil is slightly acid or neutral.

In many places a small quantity of gravel is distributed throughout the soil but not in sufficient quantity to hinder cultivation or to reduce appreciably the water-holding capacity. The soil is easy to cultivate, the texture ranges from loam to silt loam, and the water-holding capacity is good. There is sufficient friability and pore space to provide desirable conditions for percolation of water, deep penetration by plant roots, aeration, oxidation, and bacterial activity. Few areas are inundated by annual or perennial floodwaters, and in many places where grasses have been established the surface soil is slightly darker and slightly higher in organic matter than the subsoil.

Snow silt loam is a fertile soil, and most of it is cultivated. Wheat is raised on a large part of the area, but where water for irrigation is available alfalfa is the principal crop, and fruits are produced along the Walla Walla River east of Milton. In most places the water used for irrigation is diverted from adjacent streams, and the quantity provided and the length of the irrigation season differ in practically every area. Owing to this condition, yields of alfalfa range from 2 to 8 tons an acre. Wheat yields 25 to 60 bushels, depending upon location, rainfall, texture, depth of soil, and the quantity of organic matter in it. Prunes yield about 100 pounds a tree, or 5 to 6 tons an acre; apples, about 4 boxes a tree, or 250 packed boxes; and cherries, about 75 pounds a tree, or 3 to 3½ tons. Large trees in prime condition produce somewhat higher yields. The quantity of water used for irrigating crops is limited in some places almost to floodwaters during spring runoffs and is less than 1 acre-foot. Where the supply is ample, about 3 acre-feet of water is applied on alfalfa and in orchards. In some places where rather clean gravelly material underlies the soil at depths of 4 to 6 feet, the quantity of water applied during the season is more nearly 5 acre-feet.

Caldwell silt loam.—This soil is generally smooth or gently sloping. The slopes range from nearly flat to as much as 3 percent. Drainage is generally comparatively slow, but not sufficiently so to be a serious problem. The parent materials are alluvium from higher lying lands. Some of the soils owe their dark color to soil-forming processes since deposition, and others represent dark soil material that has been redeposited. The areas north and west of Milton consist of fine-textured materials that have been washed from high-lying areas and deposited by floodwaters of the Walla Walla River or other smaller streams. Although much of the material may have been high in organic matter when deposited, the humus content has since been increased by accumulations from decayed grasses and various other plants, the growth of which has been accelerated by abundant soil moisture, as seepage from local springs. The soil material of the several areas adjacent to streams near where they emerge from the mountains consists of redeposited sediments from dark-colored soils.

Caldwell silt loam occurs most extensively north of Milton, but several areas are near Umapine, others are near Athena and adjacent to streams south of Weston, and two bodies are southwest of Cayuse. The total area mapped is 4.2 square miles.

The 8-inch surface layer is weak-brown friable and granular noncalcareous silt loam or heavy silt loam, and when moist it is almost black. Between 8 and 36 inches the soil material is not so high in organic matter and is a shade lighter in color than the surface soil. This layer is highly granular and friable and is easily crushed to very small granules or to a powdery mass. It is underlain by pale-brown slightly compact heavy silt loam or silty clay loam, slightly to very highly mottled with gray, rusty-brown, or black stains. The mottling is due to poor drainage and fluctuations in the water table during wet and dry seasons. The height of the water table and the length of time in which it is high vary from place to place. Closely associated with variations in the water table are differences in the degree of aeration, oxidation, or deoxidation, which, in turn, influence the depth at which mottling occurs, the extent of mottling, and the differences in color of the subsoil. There are only a few small areas where the water table is always within 5 feet of the surface, and nearly everywhere the high water table exists only for a few weeks. As a result plant roots penetrate below a depth of 5 feet in most places.

In the areas north of Milton, the quality or quantity of the fruit harvested is probably reduced by the high water table, which keeps the soil cold until late in spring and retards the growth of most deep-rooted plants. In other places, because of an added supply of water, the high water or seepy condition is beneficial, especially for grain crops and pasture grasses, and yields average higher than on very similar, though better drained, land. Wheat yields 50 to 65 bushels an acre, depending upon moisture conditions; alfalfa, 5 to 8 tons; prunes, about 6 tons; and apples, about 300 packed boxes. The quantity of water used for irrigation of orchards or of alfalfa is usually not more than 2 acre-feet. Prunes and apples are grown on about 1,200 acres, alfalfa on 300, and wheat on the rest. Artificial drainage of land planted to trees would probably increase both the quality and quantity of marketable fruit.

Caldwell silt loam, saline phase.—This phase occurs in valleys or in old river flood plains where drainage is, or has been, sluggish or where a high water table has prevailed for rather long periods. Seepage from adjacent higher lying areas or underlying impervious layers, such as basalt, have led to poor drainage conditions. The soil material is fine-textured alluvium, much of which has been washed from dark-colored soils of the uplands. A part of the dark color probably has been inherited from these dark soils of the uplands, but in most places it has been intensified by further accumulations of organic matter from the growth of water-loving grasses and other plants. Seepage and a high water table have favored the capillary rise and evaporation of water charged with salt, with the result that variable quantities of salts have accumulated at or near the surface. Areas that contain sufficient quantities to have slight or moderate effects upon crops and areas with such high accumulations that commercial crops cannot be produced are indicated on the soil map by special symbols.

The most extensive bodies of this soil are a few miles west and southwest of Stanfield, but others are scattered throughout the area. There are several in Walla Walla Valley, a few are east and southeast of Pendleton, and others are in valleys north of Adams and Athena. The relief ranges from nearly flat in some places to gently sloping in others. The total area mapped is 8 square miles.

The surface soil to a depth of about 18 inches is pale brown or light brownish gray when dry and dark brown to black when moist. In most places it is calcareous. It is a friable granular silt loam, high in organic matter. Between 18 and 24 inches is firm but friable pale-brown to light brownish-gray granular silty clay loam, and when moist it is brownish gray to dusky brown. This layer may or may not be calcareous. It is underlain by pale-brown to very pale-brown firm but friable granular silty clay loam of a browner cast than the layer above, but containing less than half as much organic matter, and in most places calcareous. This layer continues to a depth of 6 feet or more, but in some places at a depth of about 60 inches it is underlain by very pale-brown friable fine sandy loam that usually continues to a depth of 6 feet or more. The entire soil is alkaline.

Reclamation of salt-affected soils is dependent upon a drainage system that will prevent seepage in some areas and in others will lower the water table to 5 feet or more below the surface. Each area presents drainage problems peculiar to itself. In some places by the use of intercepting drains and the provision of better outlets in low places it is possible for the soils to be soon freed of excess water and for harmful quantities of salts to be leached out. In the flatter areas of the Walla Walla Valley and in the bodies west and southwest of Stanfield, drains might be installed or the drainage waters might be pumped to lower the water table. The feasibility of such procedures is questionable, however, because of a flat gradient and in many places because of the impervious and uneven underlying surface of solid basaltic bedrock. In the irrigated districts where drainage is adequate, the land may be reclaimed by leaching the salts from the soil.

Caldwell silty clay loam, saline phase.—This soil occupies flat or gently sloping bottom lands where soil material eroded from higher lying lands has been deposited in flood plains. The material probably had developed a dark color before it was eroded and redeposited, but this color has been further intensified by the decay of water-loving plants that grew in these poorly drained areas. Small areas occur in Walla Walla Valley and others southwest of Stanfield. A total of 1.4 square miles is mapped.

To a depth of 8 inches the soil when dry is brownish-gray slightly compact noncalcareous silty clay loam, and when moist, is brownish black. It breaks into fine blocks and coarse granules. Below 8 inches and to a depth of 20 inches the soil is not so high in content of organic matter and is light brownish gray when dry and brownish black when moist. Although slightly compact, it breaks easily into large and small granules. Between 20 and 36 inches is pale-brown friable granular noncalcareous light silty clay loam in which the content of organic matter is much lower than in the upper layers. Below this and extending to a depth of 50 inches, the material is similar in texture, structure, reaction, and color, but it is somewhat mottled with faint gray and rusty-brown stains, which indicate poor drainage or at least fluctuations of the water table. In many places this material continues to depths of more than 6 feet but in others it is underlain by pale-brown to very pale-brown friable or slightly compact heavy noncalcareous silty clay loam highly mottled with gray and rusty brown. Most of the soil near Umapine is practically free from salt accumulations, although small acreages are slightly affected. Usually the surface soil in the affected areas and occasionally the entire profile contains small quantities of calcium carbonate.

Bodies about 2 miles southwest of Stanfield are either slightly or strongly affected by salt accumulation and are generally calcareous in either the surface or the entire soil. The texture of the surface soil in these bodies is lighter than in the soil west of Umapine. The soil itself is permeable, but seepage from higher lands, flatness, and comparatively impervious substrata make for poor drainage. The possibility of reclamation of these tracts is dependent upon a drainage system that will keep the water table 5 feet or more below the surface.

Southwest of Stanfield, however, the water table is so near the surface most of the year that the drainage condition, together with the salt accumulation, precludes the use of the land other than for pasture. Saltgrass, bluegrass, sedges, and weeds grow on this soil and are used as green pasture for dairy or beef cattle. In areas where half the pasture consists principally of saltgrass and half of bluegrass, the carrying capacity is one cow to the acre. In spring and summer 1 acre will supply feed for more than one animal, but in winter the quantity available is not sufficient for one cow.

Hermiston silt loam.—This soil generally occupies low terraces or very gentle slopes above first bottoms and below extensive higher lands, although some areas occupy bottom lands of narrow valleys or draws ranging in width from a few feet to more than a quarter of a mile. One extensive area is near Adams; others are in the vicinity of Athena, in the Butter Creek Valley, and near the Umatilla River between Echo and Nolin. The relief is generally nearly flat or very gently sloping, and drainage varies from good to poor. In places soluble salts have accumulated to a slight or moderate degree. One of the contributing factors to poor drainage is that certain of the areas are subject to runoff and seepage from adjoining higher lands. A total area of 11.2 square miles was mapped.

The soil material consists largely of fine-textured wind-blown material (loess) that has been washed from higher lying districts and redeposited on flood plains, low terraces, or colluvial slopes. Grasses have been the principal form of vegetation, and these have increased the humus content and darkened the color of the surface soil. This differs in the various areas, being generally darkest in the higher lying areas south, east, and northeast of Athena. Areas in the central parts of the wider valleys are commonly darker than those near side slopes or in narrow valleys.

The 8-inch surface layer is friable noncalcareous silt loam, light brownish gray to brownish gray when dry and dusky brown when moist. Below this and continuing to about 16 inches, the material is similar in color, texture, and reaction but slightly more compact or firm. It may, however, be easily crushed in the hand to a powdery mass. Between 16 and 32 inches, the soil is friable silt loam, slightly lighter in color and slightly calcareous. Underlying this is a pale-brown or light brownish-gray friable and highly calcareous silt loam that generally continues to a depth of 6 feet or more. In some places it contains considerable very fine sandy material with a gray-ashy appearance and many irregular-shaped gray concretions of calcium carbonate ranging in size from about the diameter of a pinhead to 2 millimeters. The deeper substratum is solid basaltic bedrock. In places immediately overlying the bedrock are firmly cemented layers ½ to 3 inches thick containing a large proportion of accumulated gray or white calcium carbonate. The entire soil is very friable, and structural aggregates are only feebly developed. The surface soil is slightly alkaline, and the subsoil contains small to appreciable quantities of soluble salts, though generally not sufficient to affect the growth of crops seriously. Plant roots are numerous in the upper layers, and fine roots generally penetrate below a depth of 6 feet. When saturated with water, the soil readily falls apart and is easily gullied by excessive runoff.

The areas in Butter Creek Valley that have been shown on the map as Hermiston silt loam differ slightly in that both the surface soil and the subsoil are slightly more compact, there is less gray ashy material, and the calcium carbonate appears generally as flecks or gray mottlings. The surface soil is neutral or slightly alkaline, and the lower layers are moderately alkaline.

Nearly all the areas in the vicinity of Adams and Athena are used for growing wheat. The more extensive bodies near Adams and areas at higher elevations farther east and south produce an average of 35 bushels to the acre. In places where the level of the ground water is comparatively high during part of the year yields of 45 to 50 bushels are obtained, and in areas west of Adams and southeast of Pendleton the yield averages about 30 bushels. The usual summer fallow methods are practiced, and when the spring runoff is excessive from melting snow or unusually heavy rains, gully and sheet erosion are severe on the comparatively small areas of steeper slopes where they are cultivated or unprotected. Planting strips of crested wheatgrass or other grasses should help to conserve this soil and to obtain eventually higher crop returns. Physical conditions are such that it is not practical by artificial means to divert seepage water from the side slopes where they merge with the more level lands. Very few areas are adversely affected in this way and some are benefited by a moderately high ground-water level.

Wheat, barley, and alfalfa are raised on about two-thirds of the areas of this soil in the Butter Creek Valley, and the rest is in pasture lands, which produce downy bromegrass and saltgrass, with some rabbitbrush, Russian-thistle, and weeds. The carrying capacity of grazing areas is very low, and approximately 6 acres are needed to supply feed for one sheep for 4 months. After summer fallow, wheat yields about 20 bushels an acre and barley about 35 bushels. Irrigated alfala yields about 2½ tons. The yield of alfalfa is low because of the limited water supply. If the supply were ample to continue irrigation throughout the growing season, the yields probably would average about 6 tons an acre.

Hermiston very fine sandy loam.—Similar in most of its characteristics to Hermiston silt loam, this soil is associated principally with the Walla Walla soils but is distributed more widely over the Umatilla area than any of the others. It occurs in the valleys near or in the foothills of the mountains from northeast of Milton to north of Pilot Rock and extends as far westward as Echo. Other areas are in Butter Creek Valley south of Hermiston. The total area mapped is 17.9 square miles.

Hermiston very fine sandy loam has developed largely from fine sandy alluvial materials washed from the soils of the uplands. Much of it was originally loess, and it includes much floury volcanic ash. The comparatively dark color has resulted from the incorporation of organic matter from the decay of grasses. Its position in valleys is such that runoff water from adjacent higher lying lands collects on the surface at times in many places, and seepage results in a high water table. In places the ground water contains sufficient salts to cause harmful accumulations. The valley bottoms range in width from a few feet to more than a quarter of a mile. The surface is generally smooth and gently sloping, with slightly steeper gradients where the bottom lands merge with hill slopes.

The 9-inch surface layer is light brownish-gray friable noncalcareous very fine sandy loam. In Butter Creek Valley the texture of the surface soil of most bodies is fine sandy loam. Between depths of 9 and 15 inches the material is of similar color but is mildly calcareous silt loam that breaks readily into small clods and fine granules. This grades into pale-brown mildly calcareous friable silt loam, with less organic matter than the upper layers and breaks easily into small clods, small soft granules, or a powdery mass. At a depth of 30 inches it is underlain by a very pale-brown moderately calcareous silt loam weakly cemented by calcium carbonate. The lighter color is caused in part by the calcium carbonate, which occurs in spots and seams together with some gray ashlike material. At about 38 inches, this grades into very pale-brown friable mildly calcareous fine-textured loam, which continues to a depth of 6 feet or more. The substratum consists of indurated basaltic rock.

The surface layer is almost neutral in reaction, but the lower ones are alkaline. The gray ashy material and calcium carbonate in the subsoil occur in some places as finely divided powdery material, rather evenly distributed throughout the soil, but in other places there is a distinct gray or white weakly cemented layer that is high in ash and calcium carbonate. A moderate quantity of organic matter occurs to an average depth of 15 inches, but below this it is low.

The unusually wide distribution of this soil is accompanied by some differences in color and other profile characteristics. Generally, the areas that lie at higher elevations and nearer the mountains are a shade darker, contain slightly more organic matter, have less ash and calcium carbonate in the subsoil, and are more highly productive.

Most of this soil is used for producing wheat by summer fallow methods. In the vicinity of Adams and near the mountains wheat yields 35 to 50 bushels an acre, depending upon the rainfall, the water received by runoff or seepage from adjacent higher lying land, and comparative freedom from harmful accumulations of salts. West of Adams the yields are less, but usually where the soil is associated with the Walla Walla or other dark-colored soils, yields range from 25 to 35 bushels. Farther west where the soil is associated with relatively light-colored soils, the yields range from 15 to 25 bushels, depending largely upon the moisture available to produce crops. Several bodies near Adams and Athena contain appreciable quantities of salts. In such places, yields are either lower or the grain is of poorer quality. Grain growing is not practical on the areas with the greatest salt concentration.

A few small bodies in Butter Creek Valley that are irrigated are planted to alfalfa, the yields of which depend largely upon the quantity of water available for irrigation. In the very limited area where as much as 2½ acre-feet are available for distribution throughout the growing season, yields as high as 6 tons are obtained, but the supply of water derived from Butter Creek is usually much less, and instead of the more desirable distribution throughout the season, water is available only during periods of runoff in spring, when the flow of the stream is diverted and spread over the land. The quantity of water available as well as the duration of the flow varies in different years, with the result that the yields of alfalfa range from about 1 to 3 tons an acre.

Hermiston very fine sandy loam is friable and easy to cultivate. It absorbs water readily, has a relatively high water-holding capacity, and contains a moderate quantity of organic matter. Generally, it is well adapted to the production of wheat, but as a result of the present system of summer fallow, incipient gullies cause serious erosion in places on comparatively gentle slopes during periods of heavy rainfall or excessive spring runoff from melting snow. In some places deep gullies have caused serious losses of soil. A low supply of organic matter, soft consistence, and lack of granulation and coherence all make this soil erodible. Crested wheatgrass grown on the steeper slopes or in strips across fields might serve to prevent serious erosion and to conserve the productive qualities of this soil.

Onyx loam.—Occurring in numerous bodies in old stream flood plains, some of the low-lying areas of this soil are inundated when exceptionally heavy runoff follows rapid melting of snow. There are many bodies in the Walla Walla, Umatilla, and Butter Creek Valleys, and others are adjacent to smaller streams. The soil is closely related to Snow silt loam, but is lighter in color, as it occurs farther from the mountains where the rainfall is lower and much of the soil material has been washed from soils of lighter color and lower content of organic matter. The total area mapped is 13.6 square miles.

The surface is gently sloping, but because of the position of soil areas in flood plains near drainage channels, many bodies are narrow or are dissected by side channels. Drainage is generally good throughout, although some seepage occurs in places where the areas merge with higher lying lands. The entire profile is friable and sufficiently open to insure good internal drainage, aeration, and oxidation and to be favorable to bacterial activities.

Virgin or uncultivated areas support a variety of plants. Downy bromegrass, sagebrush, rabbitbrush, giant ryegrass, and a number of weeds are common, with brush and willow and cottonwood trees along the drainage channels. Bluegrass and clover grow on many areas that at one time were cultivated but are now abandoned.

The 8- to 14-inch surface layer is pale-brown friable heavy loam containing a moderate quantity of organic matter. Below this to a depth of about 40 inches is light brownish-gray to very pale-brown heavy fine sandy loam much lower in organic matter. Between depths of 40 inches and 6 feet the subsoil is pale-brown to very pale-brown or brownish-gray friable silt loam with less organic matter than the subsurface layer. The entire soil is slightly alkaline but noncalcareous. Many areas are included that have silt loam or heavy silt loam textures in the surface and subsoil layers. The color of the surface soil varies also in different parts of the area. When dry it is pale brown, but when moist it is dark and closely resembles the color of the Hermiston or Snow soil types. In Butter Creek Valley several bodies are brownish gray and the organic matter averages slightly higher than normal.

A body about 2 miles east of Yoakum consists of materials deposited in waters impounded by a dam across the Umatilla River and consisting of many layers of soil materials, ranging from fine sandy loam to heavy silt loam in texture and from light brownish gray to weak brown in color. Several bodies are underlain by gravelly materials at depths of 4 to 7 feet. These and others that have gravel distributed on the surface and through the soil are indicated on the map by gravel symbols. These bodies are generally somewhat less fertile and less productive than the more typical ones, which are deep, friable, and without any noticeably porous droughty layers in the subsoil or substratum.

The soil is easy to cultivate, absorbs moisture readily, has good water-holding capacity, and is not droughty, and about 85 percent is cultivated. It is well adapted to crops, and good yields are obtained in all irrigated districts where sufficient water is available. About 80 percent of the cultivated area receives some irrigation, and the principal crops in the order of importance are alfalfa, corn, barley, wheat, tree fruits, bluegrass or mixed pasture grasses, potatoes, squash, and garden vegetables. The dry-farmed areas are used principally for wheat, which yields 20 to 40 bushels an acre, depending upon the available moisture, which may be derived either from rainfall or from rainfall plus runoff and seepage from higher lying land. Under irrigation, yields are closely correlated with the quantity of water applied. With an adequate water supply, alfalfa yields 5 to 7 tons an acre, with an average of 6 tons; corn for grain, 38 bushels, and for fodder, 11 tons; barley, 75 bushels; wheat, 35 bushels; potatoes, 150 to 250 bushels; squash, about 10 tons; prunes, 6 to 8 tons; and apples, about 280 packed boxes. The carrying capacity of pasture in mixed grasses is 1 acre for two animal units, or it will produce about 3 tons of cured hay. Yields are less when water is available only for short periods in spring and early in summer. The irrigated areas of wheat and barley are principally in Butter Creek Valley. Much of the land formerly in alfalfa in that valley has been replaced by grain when the local runoff has been unusually low. Alfalfa plants become weakened by a shortage of water, and during unusually cold winters they have been killed.

Onyx fine sandy loam.—This soil occurs in many small bodies in Walla Walla Valley, in the Umatilla Valley from near Pendleton to Umatilla, in Butter Creek Valley, and in smaller valleys east of Stanfield and near Hermiston. The total area mapped is 7.3 square miles. The surface is generally nearly flat or very gently sloping and well suited to irrigation. Most of the soil materials have been washed into the valleys from the uplands forming each watershed, but in places there is considerable loess, or wind-blown material. Internal and external drainage are good.

The surface soil to a depth of 8 inches is pale-brown, weak-brown, or light brownish-gray friable fine sandy loam with a moderate or low content of organic matter. Beneath it is pale-brown or very pale-brown friable fine sandy loam very low in organic matter. In some places the subsoil contains a few layers of both slightly lighter and slightly heavier textured material. The entire profile is friable, contains appreciable pore space, and has good water-holding capacity. The surface soil and subsoil range from slightly acid to slightly alkaline, and in some places the subsoil is moderately alkaline. In grass- or brush-covered areas plant roots are numerous in the surface soil, and many fine roots penetrate below 5 feet, or to the depth that moisture penetrates.

About 1,600 acres are irrigated and produce principally alfalfa, fruit, and potatoes. Alfalfa yields 3 to 6 tons an acre, prunes about 6 tons, apples about 270 packed boxes, and potatoes about 170 bushels. The rest of the land is used for grazing sheep in spring and winter. Where sufficient water is available the land supports a stand of sagebrush 2 to 5 feet tall, together with downy bromegrass, rabbitbrush, Russian-thistle, giant ryegrass, mustard, and other less conspicuous plants. As the soil usually occurs in low places, considerable moisture is stored in it during periods of heavy runoff. Other moisture in the form of seepage from higher lying adjacent land also benefits plants in places. The carrying capacity, therefore, is dependent to a considerable extent on the moisture available to plants, and ranges from about 20 to 40 acres for one animal unit.

Onyx loamy fine sand.—This soil occurs on flood plains of streams where the material has been washed or blown from the uplands. The surface is smooth or gently sloping and in places is slightly hummocky. The soil is porous and absorbs moisture as rapidly as received. Internal and external drainage are good. The most extensive bodies are in Stage Gulch between 3 and 5 miles east of Stanfield, several others are near the Umatilla River between Stanfield and Umatilla, and one small body is in Butter Creek Valley at the southwestern margin of the area. The total area mapped is 2.9 square miles.

The 8-inch surface layer is pale-brown loose noncalcareous loamy fine sand with little organic matter. Below this and to a depth of about 30 inches the material is slightly lighter in color and contains slightly less organic matter. Between 31 and 56 inches is pale-brown loose noncalcareous loamy fine sand and fine sand of slightly lower organic-matter content than the layer immediately above. In many places this layer continues to a depth of 6 feet or more, but in others the material is a very pale-brown friable or loose mildly calcareous loamy fine sand and loamy sand. Basaltic bedrock occurs at depths of about 6 to 20 feet or more.

About 180 acres are irrigated for alfalfa and corn. Alfalfa yields 2½ to 3½ tons an acre, and corn about 30 bushels of grain, or 8 tons of fodder. The soil is easy to cultivate and grows many crops well, but because of its open and droughty character it requires large quantities of water. To produce a yield of 3 tons of alfalfa about 6 acre-feet of water are used each season. Less water would be required if it were so distributed as to minimize loss by deep percolation. Some areas are situated low enough to be subirrigated by seepage water from higher lands and consequently are valuable for pasture. In such places bluegrass, green bristlegrass, strawberry clover, sweetclover, ragweed, and Sudan grass and several less conspicuous weeds are common. Most of the soil is without any irrigation water and is used only as pasture for sheep in winter and early in spring. Downy bromegrass, Russian-thistle, tarweed, mustard, and a few other short-lived plants provide most of the dry-land forage. Other plants growing on the soil include sagebrush, rabbitbrush, and giant or wild ryegrass. The carrying capacity of dry land is approximately 35 acres for one animal unit.

Yakima cobbly loam.—This soil is very stony, porous, and excessively drained and occurs principally in one extensive body and several smaller ones near Milton and in the delta and former flood plain of the Walla Walla River, and others are adjacent to the Umatilla River. The total area is 10.1 square miles. Practically all the cobbly and gravelly material, which characterizes these alluvial deposits, has been derived from the basalt that underlies the drainage basins of the Walla Walla and Umatilla Rivers. Areas near Milton constitute parts of an alluvial fan-shaped delta that slopes gently to the north and west. Internal and external drainage are good to excessive. A few of the moist virgin areas near streams support a growth of cottonwood, willow, and alder trees with underbrush or vines; other somewhat drier areas support a cover of wild rose, downy bromegrass, and some bluegrass. Much of the land, however, is cultivated.

The 12-inch surface layer of Yakima cobbly loam consists of pale-brown friable stony loam moderately low in organic matter. When the soil is moist, the color ranges from dusky brown to dark brown. Pieces of well-rounded basalt gravel and cobblestones ranging from fine gravel to stones 6 inches in diameter form 25 or 30 percent of the material. Below this and to a depth of about 26 inches is a pale-brown or brownish-gray layer of cobbly and gravelly material comparatively high in sand but moderately low in organic matter. Although this layer is very porous, it will stand almost vertically in a cut bank. About 50 percent is cobblestone or gravel, and less than 10 percent is finer than medium sand. Below 26 inches and to a depth of 5 feet or more is a loose porous bed of brownish-gray basaltic cobbles, gravel, and sand.

The entire soil is noncalcareous, open, and porous. The surface and the lower layers are about neutral, and crops do not respond to applications of lime. The numerous plant roots of the surface soil penetrate the underlying materials to various depths, approaching 3 feet. Because of the open character of the soil, soluble salts have not accumulated and the entire profile lacks free calcium carbonate.

The soil is variable in depth, in content of gravel and stone, and in surface texture and color of the finer soil material. Spots, presumably former depressions, contain somewhat finer and darker colored surface soil. In places the surface is so thickly covered with cobbles that little or no soil is visible, and the soil to plow depth contains 50 percent or more of stone and gravel. Many fields have been partly cleared of stone, but most of them are still very stony. The fine-textured surface soil varies in depth, but rarely extends to a depth of more than 20 inches.

Where irrigation is practiced in the Walla Walla Valley, Yakima cobbly loam is used principally for the production of prunes, apples, cherries, melons, tomatoes, alfalfa, and other less important crops. Farm tracts are relatively small, averaging less than 20 acres. Because of the large number of cobblestones, tillage is very difficult and is usually done by the use of horse-drawn implements. Orchards are irrigated at intervals of 3 to 10 days by furrows. Alfalfa is grown in the orchards as a soil-improving crop. As it is not harvested, but is allowed to go back into the soil, much of it must be reseeded about each third or fourth year. Prunes yield about 4½ tons an acre, apples about 235 packed boxes, cherries about 4,000 pounds, tomatoes about 410 lugs, watermelons about 7 tons, and muskmelons or cantaloups about 160 crates. When grown alone, alfalfa produces 2 to 3 tons an acre.

Several areas in the Umatilla River drainage basin are cultivated, but many are uncleared of stone and, compared with irrigated tracts that have been leveled, their surfaces are uneven. Generally very little forage or range feed is produced on virgin areas. The water requirement of this soil is excessive, and the agricultural development of virgin bodies is apparently too costly to be justified. Under dry farming the productivity is low and tillage is difficult.

Yakima gravelly loam.—This soil is excessively drained and droughty. It has been developed mainly from gravel deposits laid down on the former flood plains of the Umatilla and Walla Walla Rivers and their tributaries. The gravel is rounded and almost entirely of basaltic origin. Practically all calcium carbonate has been leached away. The surface soil and subsoil are nearly neutral in reaction. In the grass- and brush-covered areas plant roots are numerous in the first few inches of the surface layer but become less numerous with depth. In irrigated districts tree roots penetrate more than 6 feet below the surface, although most of the feeding roots are in the upper 2 feet. The color of the surface soil ranges from pale brown or light brownish gray to a weak brown when dry and from weak brown to dark brown or dusky brown when moist. The darker soil has developed in depressions or other places where more moisture is available and the growth of grasses has been more than average.

Extensive areas of this soil are near Milton and Umapine in the Walla Walla Valley and near Pendleton in the Umatilla Valley and within the city boundaries at Pendleton and Milton, with other areas at various places along the Umatilla and Walla Walla Rivers. The total area mapped is 7.5 square miles. The surface is nearly flat to gently sloping. A few ridges about 10 inches high and ranging in width from a few feet to 300 feet and depressions of similar size are common surface configurations, though subject to change by deposition and erosion during flood periods. A few channels, presumably occupied by streams that deposited the gravelly sediments, are now apparent, but none has been formed recently.

Downy bromegrass, some bluegrass, rabbitbrush, sagebrush, and a number of weeds occupy virgin areas and afford some pasture during the spring months. In summer and fall the soil is usually very dry and, supporting very little green growth, has a low grazing value. Some areas adjacent to the streams, where moisture is available in the deeper subsoil, support willow or cottonwood trees, vines, and wild rose and other bushes that afford some shade and have some browsing value in spring and summer.

The 8-inch surface layer is pale-brown friable gravelly loam with a moderate quantity of organic matter. When moist the color is dark brown. Gravel constitutes about 5 percent of the material in the surface layer, although in places it makes up as much as 20 percent. It is well rounded, small, and does not greatly hinder cultivation. Between 8 and 24 inches the soil is slightly lighter pale brown and has slightly less organic matter, and the gravel, which is much more prevalent, constitutes about 20 percent. Beneath this and to a depth of about 38 inches the soil is of similar pale-brown color, but it is looser and consists of about 60 percent gravel. The pebbles average much larger than those of the surface, many being as much as 3 inches in diameter. Below a depth of 38 inches and continuing to 6 feet or more is a mixture or alternate layers of brownish-gray gravel, coarse sand, and fine sand, 50 to 60 percent of which consists of gravel and cobbles.

Although a considerable part of Yakima gravelly loam is used in spring for what grazing it affords, other areas are irrigated, cultivated, and used for the production of alfalfa, prunes, apples, cherries, berries, and tomato, melon, and other truck crops. Average acre yields are: Alfalfa, 2 to 4 tons; prunes, 4 to 6 tons; apples, 250 packed boxes; cherries, about 5,000 pounds; tomatoes, 425 lugs, or 11,900 pounds; cantaloups, 180 crates; and watermelons, about 9 tons. On irrigated pastures bluegrass is the principal grass.

The soil is so open and porous, especially in the subsoil, that most crops are irrigated each 10 days, in some places weekly. The quantity of water used in orchards ranges from 5 to 10 acre-feet or more. Alfalfa requires as much water as trees, or even more, but much less water is used on truck crops, as their growing period is much shorter. Alfalfa is the principal cover crop grown in orchards. It is planted and allowed to grow throughout the season without being cut or disked in, because in this shallow soil most plant nutrients are in the first 2 feet, and farmers fear that even shallow cultivation may cut or injure many feeding roots of trees. Alfalfa generally is not long-lived, and as much of it is replaced or crowded out by various grasses and weeds, new seedings are usually made each third or fourth year. A few farmers are now using mixed commercial fertilizers in orchards.

Yakima loam.—This soil occupies a total of 2 square miles in several small bodies in the Umatilla Valley east of Pendleton and in the Walla Walla Valley near and west of Milton. The surface is gently sloping and has developed largely from stream deposits washed from the mountains, but there is some admixture of other materials washed or blown from local areas. It is similar to the other soils of the Yakima series in that it is characterized by gravelly and open subsoil and substrata.

The surface soil is pale-brown friable noncalcareous loam or silt loam to a depth of about 8 inches, underlain to a depth of 20 to 40 inches by similar material, slightly lighter in color and slightly lower in organic matter. The subsoil and substratum to a depth of 6 feet or more consist of fine to coarse water-worn basaltic gravel and sand. The loose porous nature of this material and its almost complete lack of silt and clay are responsible for its droughty character. The surface layer and the lower layers range from slightly acid to slightly alkaline.

Parts of the areas in Umatilla Valley are cultivated and used for growing wheat by dry-farming methods, and parts for raising alfalfa, potatoes, and vegetables under irrigation. East of Pendleton under dry-farming methods yields of wheat are 15 to 25 bushels an acre, depending upon the depth of the soil over gravel and the quantity and distribution of the rainfall during the growing season. Other areas are used only for pasture, the grazing value of which is low. Some of the land in the mountains or near the streams where moisture conditions are good is covered with alder, maple, cottonwood, or pine trees. Where trees are growing, the water table usually rises to within 5 feet of the surface for part of the year. In the Walla Walla Valley most of the soil is irrigated and alfalfa or fruit trees are grown. Alfalfa yields 2 to 5 tons an acre, depending upon depth of the soil over gravel and the quantity of water applied. Prunes yield about 5½ tons an acre and apples about 250 packed boxes. As areas of Yakima loam are generally small and cut up by drainage channels, the cost of cultivation is comparatively high.

Yakima silt loam.—Areas of this soil are associated with those of Snow silt loam. Though similar to the other Yakima soils in being underlain by clean water-worn gravel at depths of 12 to 36 inches, it differs in having a darker colored surface layer. The underlying gravelly materials were deposited in the valleys of streams emerging from mountainous districts. Because of the gravelly subsoil drainage is excessive. A total area of 1.3 square miles is mapped.

The surface soil when dry is a weak-brown friable and granular noncalcareous loam or silt loam and dusky brown or brownish black when moist. From a depth of 8 inches and continuing to the gravelly subsoil the material is of similar texture, structure, consistence, and reaction, but slightly lower in organic matter and the color is not so dark. The gravelly subsoil generally continues to a depth of 6 feet or more. The soil material above the gravel has desirable characteristics for cultivation, percolation, water holding, and root penetration, but this soil is much less desirable for farming than the Snow silt loam, because of the porous and open character of the subsoil.

Like Snow silt loam, this soil is used for growing wheat, but alfalfa is the principal crop where water is available for irrigation. The quantity of water used in the different fields varies with the depth of soil overlying the gravelly subsoil. In places, comparatively frequent irrigation is required. Wheat is grown by summer fallow dry-farming methods, and alfalfa and fruits are irrigated. The yields depend on depth of soil over gravel and the quantity of irrigation water applied.

Wheat yields 25 to 30 bushels an acre, alfalfa 2 to 5 tons, prunes about 5 tons, apples about 250 packed boxes, and cherries about 50 pounds to the tree.

Included with Yakima silt loam are a number of areas where either the gravelly subsoil is covered by less than 12 inches surface soil or the latter consists of gravelly loam to depths ranging from 12 inches to 3 feet or more. Below the gravelly loam is comparatively clean gravelly material that continues to a depth of 6 feet or more. Areas in which the soil is gravelly at or near the surface are indicated on the map by gravel symbols. A body about 1 mile southeast of Harmony School has both gravel and stone scattered over the surface and throughout the soil, but only parts of it are cultivated, and yields of alfalfa are not satisfactory.

Stanfield very fine sandy loam.—This soil occurs in low-lying areas in districts of low rainfall where seepage or a high water table have aggravated poor drainage conditions and favored the accumulation of salts and the formation of a cemented hardpan. Several areas are in the Walla Walla Valley and others are near Stanfield, in Butter Creek Valley, and in valleys near Athena, Adams, and south of Pendleton. The total area mapped is 9.1 square miles.

The relief is smooth and ranges from nearly flat to very gently sloping. In some places the relief is characterized by a number of depressions or concave-shaped drains that range in depth from 10 inches to 2 feet and in width from 6 to 15 feet.

The soil has been developed principally from alluvial sediments, although partly from wind-laid materials. Poor drainage and the presence of soluble salts have been important in determining the type of soil development and the resulting soil characteristics.

In all places where this soil occurs, drainage was either once very poor or is now poor. Poor drainage may be caused by one condition or a combination, including low position in relation to surrounding land, flat surface with inadequate surface drainage outlet, and impervious substrata. In some places all the permeable material above the basaltic bedrock or other impervious strata has become saturated with water. Because of arrested drainage and subsequent evaporation from the moist surface soil, a large quantity of salts has accumulated. The cemented layer apparently has formed at or slightly above the surface of the water table where deposition of materials has occurred. The native vegetation consists of saltgrass, greasewood, downy bromegrass, rabbitbrush, and, in some places, giant ryegrass.

The 9-inch surface layer is pale-brown friable noncalcareous very fine sandy loam, loam, or silt loam. Below 9 inches is a somewhat paler brown, friable, and mildly calcareous very fine sandy loam or silt loam of lower organic-matter content. A few very small soft clods have formed around minute accumulations of calcium carbonate. This layer is abruptly underlain by very pale-brown or very light brownish-gray moderately or highly calcareous loam that is rather firmly cemented into a hardpan, which is not very dense and contains many small tubular pores the size of a needle point. The cementing material consists mainly of calcium carbonate. Plant roots are numerous in the surface soil, and many penetrate to or immediately above the hardpan, where they spread horizontally and form a dense mat or mass. A few roots of woody plants penetrate through the hardpan, which ranges in thickness from less than 1 inch to 2 feet and averages about 7 inches. The hardpan is not continuous and does not occur uniformly at a certain depth. In places it is near the surface, in others it is as much as 5 feet or more below the surface, and in still others it is entirely lacking. Beneath the hardpan layer, at a depth of 30 inches and to 46 inches in one of the profiles examined, is softly cemented moderately calcareous loam or silt loam, pale brown to very pale brown when dry and weak brown when moist. Beneath a depth of 46 inches and continuing to 6 feet or more is pale-brown, friable, and very mildly calcareous silt loam, which when moist is weak brown. The surface layer is usually alkaline, and the lower ones are moderately to highly alkaline. Associated almost everywhere with this soil are appreciable quantities of volcanic ash or ashy material, which in places is rather evenly distributed and mixed with the soil and in others occurs at various depths in layers 1 inch to 4 feet or more thick.

Practically all this land is used only for saltgrass pasture. Where water is available, large areas have been flooded in some places and kept irrigated until most of the salts have been leached away and there bluegrass forms the principal cover. In some wet places near Hermiston and Stanfield, strawberry clover is common; it is highly nutritious and is preferred by livestock. The pasture acreage obtained from saltgrass or bluegrass or from areas with both saltgrass and bluegrass varies in proportion to the water available for irrigation, the duration and height of the water table, and the salt accumulations at or near the surface. Where water is applied frequently in spring, summer, and fall, each acre of saltgrass will provide pasture for one cow or about five sheep from April until the grass is frozen back, usually in October or November. Where the water table is close to the surface and no irrigation water is applied, the carrying capacity is less than one cow an acre from May until September. This is usually about as long as sufficient water is available. Saltgrass pasture serves fairly well for maintenance, but is not good for producing meat or milk. Bluegrass pasture is probably three times as valuable as saltgrass pasture, and the carrying capacity where it is irrigated regularly throughout the season is more than twice that of saltgrass. Three dairy cows may be pastured on 2 acres throughout the year, with other feed provided during the winter months only, when the grass is killed. Freezing weather precludes seasonal growth.

Most of Stanfield very fine sandy loam is so strongly affected by salts that no commercial crops can be grown. In a few places where the water table remains 4 feet or more below the surface, farmers have irrigated the land in order to leach away the salts and are now raising either barley or alfalfa. The total land in such crops is less than 250 acres, and the yields are not entirely satisfactory.

There is nothing, however, to prevent the production of good yields following adequate leaching and complete reclamation of the land. Reclamation includes (1) the provision of adequate drainage by artificial means, so that the water table will be kept 5 feet or more below the surface; and (2) the leaching of the soil by flooding with irrigation water until it is free from detrimental quantities of salts. Because of the large percentage of gray ashy material in many places, the organic matter is unusually low and in such places manure, straw, or some other form of organic material must be supplied before any appreciable returns can be expected. Where considerable sodium carbonate or black alkali occurs, reclamation may be accelerated by the application of gypsum, although this is not usually necessary where the soil is of medium texture and absorbs water readily. Where the underlying sediments are very compact or drainage is sluggish, reclamation may be very slow, though in many such places if the water table is kept 5 feet or more below the surface the salts may be leached away by applying only a few acre-feet of irrigation water over a period of a few months.

Stanfield fine sand.—The relief of this soil is almost flat or very gently sloping. In some places hummocks about 12 inches high, 10 to 30 feet wide, and 50 to 150 feet long are common. The parent material is mainly alluvial sediments together with an admixture of wind-laid fine sand deposited in the former flood plains of the Umatilla River and Butter Creek. Drainage is poor in practically all areas. Many bodies of the soil are strongly affected by accumulations of salts, and others are slightly affected. Part of an area about 2 miles southwest of Hermiston has fair drainage and has been leached to such an extent that the soil is practically free of salts. The areas most strongly affected by salts support a dense cover of saltgrass and in places a sparse cover of greasewood and some rabbitbrush. Areas slightly affected support saltgrass, and in flooded spots where there are only small quantities of salt, bluegrass, alsike clover, strawberry clover, and foxtail, and dandelion and other weeds are common. A total area of 0.8 square mile of this soil occurs south and southwest of Hermiston.

The 8-inch surface layer is pale-brown or light brownish-gray friable noncalcareous fine sand of low organic-matter content. Between depths of 8 and 23 inches the structure and texture are similar, but the soil is slightly grayer, is mildly calcareous, and contains less organic matter. Below 23 inches and to a depth of about 36 inches the material is moderately calcareous and less gray than the layer above. The lower part of this layer contains many softly cemented particles or aggregates. It is underlain abruptly by a firmly cemented very pale-brown or very light brownish-gray highly calcareous loam or fine sandy loam. This cemented layer, or hardpan, contains many small pores or tubes the size of a pin point. The thickness of the hardpan averages about 8 inches, ranging from less than 1 inch to as much as 2 feet or more. The depth at which the hardpan occurs ranges from about 10 inches to 5 feet or more below the surface. When dry the cemented layer is very hard and it is difficult to break the more highly cemented parts, but when moist the softer formations may be penetrated with a sharp auger. Beneath the hardpan is softly cemented material of similar or slightly lighter texture that may be easily bored with an auger. This layer is pale-brown highly calcareous fine sandy loam or loamy fine sand. Its thickness, like that of the hardpan, is variable and ranges from only a few inches to 2 feet. At an average depth of about 6 feet below the surface the softly cemented material is underlain by friable pale-brown mildly or moderately calcareous loamy fine sand.

Plant roots are numerous in the surface soil, or sod, and many continue to the hardpan, where they turn horizontally to form a dense fibrous mat. Where the hardpan is soft or very thin, many roots penetrate it and extend downward to a depth depending upon the type of plant and the height of the water table. Where the hardpan is comparatively thick, only a few roots of the woody plants are able to penetrate to the layer below. The surface soil is generally moderately alkaline, and the lower layers are moderately or highly alkaline.

Barley and alfalfa have been grown with fair yields on fields of the reclaimed soil about 2 miles southwest of Hermiston. Most of the soil, however, is used only for pasture. Saltgrass alone is pastured for only about 4 months and has a carrying capacity of about five sheep or one cow to the acre. Saltgrass, if irrigated regularly, may be pastured during most of the growing season, but it is not highly nutritious, and livestock feeding upon it do not make rapid gains. Where bluegrass, foxtail, and other plants occur, the carrying capacity is more than twice that of saltgrass alone, and where such pastures are irrigated regularly during the growing season three cows will do well on 2 acres. Some areas are pastured by sheep, but most of them are used in raising dairy or beef cattle.

Where drainage outlets have been provided, the soil generally has been drained effectively, flooded, leached of detrimental salt, and used for growing bluegrass or clover pasture. If the water table is kept 5 feet or more below the surface, alfalfa may be grown. To be effective, drainage not only of individual fields but also of adjacent poorly drained areas is generally required. The feasibility of drainage involves a consideration both of costs and of the probable increase in productivity.

Umapine very fine sandy loam.—The material from which this soil has developed was deposited mainly by water on former flood plains, but to some extent it consists of wind-laid deposits. Near Umapine part of the soil probably has developed from materials deposited in lakes. The relief ranges from nearly flat to slightly undulating or very gently sloping. Drainage is poor in practically all areas because of impervious or slowly pervious deep-lying strata of fine-textured silts, clays, or basalt bedrock, which retard the movement of drainage water.

There are several areas near Umapine and north of Milton, two about 1 mile and 2 miles southwest of Stanfield, and one near Butter Creek about 6½ miles southwest of Stanfield. A large part of the area about 2 miles southwest of Stanfield is lighter in texture than the others. Both surface soil and subsoil consist of fine sand. The total area mapped is 2.7 square miles.

The 8-inch surface soil is pale-brown mildly calcareous friable very fine sandy loam low in organic matter. Below 8 inches and to a depth of about 24, the layer is pale-brown mildly calcareous or noncalcareous material, somewhat higher in very fine sand, slightly lower in organic matter, and slightly paler brown than the surface soil. Between depths of 24 and 38 inches is pale-brown friable mildly or moderately calcareous loam containing much silt and very fine sand. This is usually underlain to a depth of about 54 inches by material of similar color and texture, but highly calcareous and very weakly cemented, though it can be drilled easily with an auger and can be broken or crumbled in the hand. It is penetrated easily, both by water and by plant roots. This layer represents a soft or slight development of a hardpan that has formed either at the depth to which soluble salts have been leached by rainfall or immediately above the top of a water table that apparently existed for some time. In places this layer is not present and the material is similar to that of the layer above. At a depth of about 54 inches and continuing to about 8 or 9 feet below the surface is pale-brown very fine sandy loam or loam that is friable and either mildly calcareous or noncalcareous. There are no definite structural aggregates. Stratified fine-textured calcareous sediments continue downward in some places and form the substrata, but in others there are gravelly sediments similar to those underlying Yakima gravelly loam. Many variations in color, texture, and other characteristics are common in the different areas or in different parts of the same area. Layers or lenses of gray or white volcanic ash and layers of clay loam occur at variable depths, and the subsoil in many places is highly mottled with dark rusty-brown and gray stains. Layers of gray or white ash that range in thickness from about 1 inch to as much as 2 feet or more are widespread and occur in almost every area.

The surface soil and subsoil range from slightly to highly alkaline. Plant roots are numerous in the surface soil and many continue to a depth of 6 feet or more, though to a shallower depth where the water table most of the year stands less than 6 feet below the surface.

Much of the soil is used only for pasture and supports a dense stand of saltgrass, bluegrass, foxtail, and weeds. Where the water table is 5 feet or more below the surface, however, many areas have been partly or almost entirely reclaimed and are used for growing a wide variety of crops, including barley, wheat, alfalfa, melons, and apples, and fair yields have been reported. Under irrigation barley yields about 60 bushels an acre, wheat 45 bushels, alfalfa 3½ tons, and apples about 220 boxes. In parts of the fields where the water table is higher than average or where appreciable quantities of salt remain, the yields are somewhat lower.

Most of the soil is below canals or in districts where water for irrigation is available. The soil is permeable, and where natural drainage is favorable the bodies have been or are being reclaimed by flooding with irrigation water to leach out the salts. Where seepage and drainage conditions are such that the water table rises within a few feet of the surface and salts continue to accumulate at the surface, the land cannot be reclaimed until an adequate system of drainage is installed.

MISCELLANEOUS NONARABLE SOILS AND LAND TYPES

The miscellaneous nonarable areas consist of soils and land types that are shallow, stony, steep, infertile, subject to overflow, or otherwise unsuited to crops, including Waha stony silt loam; Underwood stony loam; scabland; shallow stony soils; rough broken and stony land; rough broken and stony land, timbered phase; riverwash; and volcanic ash.

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Waha stony silt loam.—This soil occurs in many small areas on slopes and hill crests in the foothills of the Blue Mountains and in the higher part of the rolling plain adjoining the foothills. It is very shallow over the underlying basaltic bedrock and contains a very high percentage of loose basaltic boulders and smaller stone fragments. The surface soil consists of a few inches of brownish-gray granular stony silt loam or stony silty clay loam, underlain by brown tough blocky clay a few inches thick. The bedrock commonly lies within 12 inches of the surface. A total of 10.5 square miles is mapped.

The vegetation consists largely of downy bromegrass, bunchgrasses, alfileria, mustard, tarweed, a number of small flowering herbs, and some brush. The land furnishes fair range pasture, especially in spring and early in summer. About 30 acres probably will carry one animal unit. Restricted grazing and reseeding with perennial grasses is recommended to improve the carrying capacity of the land and to help check erosion. Much of this soil has been severely eroded.

Underwood stony loam.—Occupying narrow strips on hill crests or on the more gently sloping upper parts of hill and mountain slopes in the Blue Mountains, this very shallow stony soil occurs typically in woodland of western yellow pine with considerable undergrowth of grass and shrubs or in open areas with bunchgrasses, downy bromegrass, and small shrubs. It is probable that many of these open areas were once thinly timbered. A total of 5.7 square miles is mapped.

Where not badly disturbed and eroded, the few inches of surface soil is weak-brown to pale-brown friable stony loam. The subsoil is weak-brown to moderate-brown stony clay a few inches thick over basalt bedrock. It varies considerably in thickness and in degree of stoniness. In places all or nearly all the surface soil has been removed by erosion, exposing the rust-brown subsoil. Erosion apparently has followed the killing out of the perennial grasses by overgrazing and trampling by livestock.

The only uses of this soil are grazing and the production of timber. More careful control of grazing and reseeding with slender wheatgrass and other desirable perennial grasses are steps needed to maintain grass cover and control erosion.

Scabland.—This land type occupies a total of 14.3 square miles in the northwestern part of the area near the Columbia River in the vicinity of Umatilla and also near and extending several miles northeast of Cold Springs. It consists of areas in which the uneven lava beds have been only partly covered by soil material (pl. 10, *B*). Numerous large and small outcrops of bedrock protrude a few inches to 10 feet above the soil and occupy so much of the surface as to prevent the cultivation of any appreciable acreage. The soils over the bedrock are varied but are mostly from sandy wind-laid and water-laid materials. They are light in color, low in content of organic matter, neutral or slightly alkaline, and of medium or low water-holding capacity.

The rainfall in this locality is generally less than 8 inches annually and a semidesert condition prevails. Natural vegetation consists of downy bromegrass, scattered bunchgrasses, sagebrush, rabbitbrush, Russian-thistle, mustard, tarweed, alfileria, and other less plentiful weeds, grasses, and shrubs. The grasses and weeds make most of their growth in spring. Sheep graze on them in March and April and to some extent in November and December. The carrying capacity is comparatively low, about 45 to 55 acres being required for one animal unit (5 to 7 sheep).

Shallow stony soils.—Occupying a total of 78.7 square miles, these soils occur most extensively in several large bodies south, southwest, and west of Pilot Rock and in many smaller bodies southwest of Pendleton and parallel to gulches throughout the plains. The relief ranges from fairly smooth to hummocky, and the land seldom has more than a moderate slope. The rock outcrops are not so numerous as in scabland and usually do not protrude more than about 12 inches above the general surface level. Most of the stone exposed on the surface or partly buried consists of boulders or fragments of basalt. The shallow soil overlies basaltic bedrock at depths of 3 to 12 inches.

The soil material is similar to that of adjacent shallow soil types or phases. Bodies associated with extensive areas of Ritzville silt loam, shallow phase, have soil characteristics similar to that phase, but the depth to bedrock is usually not more than 12 inches and in many places is much less. Likewise, bodies associated with other soil types have characteristics similar to those soils but are differentiated by their shallowness and stoniness.

Vegetal cover in most places includes downy bromegrass, with some bunchgrass, alfileria, tarweed, mustard, sunflower, Russian-thistle, a few less conspicuous bromegrasses, sagebrush, rabbitbrush, and several small flowering plants that grow rapidly to maturity following spring rains and warm weather.

None of the shallow stony soils is cultivated. Most areas are used for pasture. Cattle, sheep, or horses pastured in stubblefields on adjacent deeper soils usually obtain some feed from the dried grass or weed growth from the shallow stony soils in fall or from green growth in spring just before the deeper soils are plowed. The value of pasture land varies in different places, but it is closely related to elevation, rainfall, vegetation, and the general productivity of adjacent soil types. The carrying capacity probably is about one animal unit to 30 or 40 acres.

Rough broken and stony land.—This land type includes steep lands, with slope gradients of 30 percent or more, and lands that are so rough, broken, or stony that cultivation is practically impossible. Narrow ravines with rocky stream bottoms, large canyons, steep rocky slopes, badly eroded steep slopes, and cliffs that rise almost perpendicularly from a few feet to 400 feet are characteristic features.

This land type, including 332.9 square miles, is the most extensive mapping unit in the Umatilla area. Wide distribution makes its characteristics vary somewhat in different parts. In the districts near Umatilla, Hermiston, and Stanfield, only a few and comparatively small bodies have been mapped where rocky hills protrude above the general level or where escarpments occur between low and somewhat higher benches. Eastward and southward, steep or rough broken areas parallel practically all the main drainage channels, and the larger bodies generally occur adjacent to the larger streams. Practically everywhere the soil covering is deeper on the slopes facing the north and east than on those facing the south and west. In the plains districts, southward- and westward-facing slopes are steepest and have the shallowest soil covering, whereas the north slopes, and to some extent the east slopes, generally are gentler and have a considerable depth of soil overlying bedrock, although outcrops of rock are common adjacent to the Umatilla River, especially between Nolin and Rieth. The most extensive bodies occupy the lower mountain slopes and extend from the foothills or upper limits of the plains well into the Blue Mountains, where they comprise the wide deep canyons of the Umatilla and the Walla Walla Rivers and their tributaries.

Almost everywhere are species of grasses, weeds, or shrubs that afford some grazing. Grass is less plentiful in the lower districts, where there is very little precipitation, and consequently grazing is generally better in the higher areas. The degree and direction of slope, stoniness, and thickness of the soil overlying bedrock, however, are probably more important than rainfall in determining the relative productivity and value of individual sites for grazing.

The principal vegetal cover in the western or lowland bodies and in the foothill or lower mountain slopes includes downy bromegrass, some bunchgrass, alfileria, tarweed, mustard, Russian-thistle, sunflower, rabbitbrush, sagebrush, and other less conspicuous grasses, weeds, and shrubs. In the higher districts are downy bromegrass, several junegrasses, some bunchgrass, bluebunch fescue, mustard, tarweed, orchard grass, timothy, bluegrasses, buckbrush, and a number of other less conspicuous or short-lived annual plants that grow rapidly to maturity in spring and summer.

Sheep are grazed in the western third of the area early in spring, they are moved to the foothills about May 1 or 15, and from there they gradually range higher into the mountains during the summer months. Cattle and horses are allowed to graze in the foothills both summer and winter. The grazing value is low, and 40 to 200 acres are required for one animal unit. The capacity can probably be increased somewhat by exercising strict control of grazing.

Rough broken and stony land, timbered phase.—The relief of this timbered phase is similar to that of the typical soil, differing mainly in that pine, fir, or other conifers form the principal vegetative cover. It includes a total area of 20.6 square miles in mountainous districts near the eastern margins of the area. The lower lying areas and many of the higher ones occupy slopes facing the north where the soil covering is deep enough and holds sufficient moisture for trees to grow. The trees include pines in many places, but usually fir, tamarack, and spruce predominate and form a moderately dense stand. Some open grass-covered or stony areas have been included.

The depth of the soil under timber cover ranges from 18 inches to more than 6 feet. The soil characteristics are similar to those of Helmer silt loam, except that the soil is commonly thinner and much stonier. In the less extensive bodies where pine trees form the principal covering, the soil characteristics are similar to those of Couse silt loam.

Timber is being cut from much of the land, but steepness of slope makes the cost of cutting and transportation much greater than on more level lands. The timber cut is used principally for fuel, although in some places lumber is cut from the larger trees. Sparsely timbered or cleared areas have some value for growing fescue, timothy, orchard grass and other less conspicuous grasses, weeds, and huckleberry bushes, but areas that are covered with a rather dense stand of trees have a very low carrying capacity for grazing—about 200 acres for one animal unit.

Riverwash.—This land type consists of sand, gravel, and boulders that occupy 12.6 square miles of stream beds, overflow channels, islands, or bars. Usually it contains very little silt and clay, although the sands may range from very fine to coarse. It is principally in or near the channels of the Columbia, the Umatilla, and the Walla Walla Rivers, where most if it is entirely under water during flood periods. There are other less extensive bodies in the flood plains of McKay Creek, Birch Creek near Pilot Rock, Butter Creek, Cold Springs Canyon, and other small creeks.

In practically all areas, the material consists of well-rounded sand, gravel, stone, and boulders principally of basaltic origin. In Birch Creek some of the gravel is granitic. Willow, alder, and cottonwood trees usually grow at the outer margins of the areas. A vine, western virgins-bower, or clematis, growing in the river bottoms climbs 10 to 20 feet high into and over the branches of trees. In some places wild rose bushes grow in the gravelly areas. On the few areas where alluvial sands have been deposited on the flood plains of intermittent streams the vegetation consists principally of downy bromegrass and sagebrush, although giant ryegrass, Russian-thistle, rabbitbrush, tarweed, and mustard are present. These latter areas furnish some grazing for sheep in March and April and again to less extent in November and December. In the Columbia River, large gravelly islands or bars that are inundated during high water are entirely barren. In general, riverwash affords very little forage for horses or cattle and has practically no agricultural value.

Volcanic ash.—Many bodies of volcanic ash are mapped in the Umatilla area, and many other small bodies have been included with other soil types. It is well mixed with other materials in many of the soils and occurs as layers in several. The ash is characteristically mealy but sharp-edged, is very porous, and has poor water-holding capacity and a very high rate of evaporation. It is found where the average annual rainfall is less than 18 inches. The total area mapped is 0.6 square mile.

The most extensive bodies occur on the leeward-, northward-, and eastward-facing slopes, where apparently the material was dropped after having been transported by the wind. It is not confined to north slopes but occupies many draws or slight depressions and is extensive at or near the base of slopes where higher lands merge with those that are comparatively flat. The relief ranges from almost flat to hummocky and rather steep. In some places considerable seepage water apparently has reached the surface, evaporated, and left deposits of salts. Because so many bodies are affected by an accumulation of salt and because the volcanic ash is often readily shifted by wind, farmers refer to the ashy places as alkali spots or as alkali blow areas, and possibly in many instances the white ash is mistaken for salts or alkali.

Many small bodies occur in association with McKay silt loam southeast of Pendleton. The largest area mapped is about 1 mile south of George Canyon School, which is a few miles southwest of McKay Lake. Several small bodies are in that general section of the Umatilla area. In many of the Hermiston, Stanfield, and Umapine soils the ash constituent is high, apparently having been washed or blown upon and mixed with the other soil material.

Because volcanic ash occurs in so many places where seepage waters approach or reach the surface and where accumulations of salts are common, the drainage features, and consequently the profile characteristics, differ greatly. In some places very salty or alkaline conditions extend throughout the entire profile and the vegetative cover is predominantly saltgrass or saltgrass combined with greasewood. In many places, however, saltgrass with both rabbitbrush and downy bromegrass are common, although the growth of each is generally very poor or scant. In a few bodies that have remained stable and have been sufficiently well drained to be leached, the surface soil at least is free from detrimental accumulations of both salt and alkali.

The 7-inch surface layer is pale-brown noncalcareous ashy very fine sandy loam. Beneath this and to a depth of about 21 inches is very pale-brown ashy friable or loose noncalcareous silt loam or very fine sandy loam containing some fine sand. In these two layers a very small quantity of organic matter has been incorporated, presumably from plant residues of grasses and shrubs. Below 21 inches and to a depth of 36 inches is light-gray mildly calcareous loose ash, consisting largely of silt and very fine sand, with very little clay or coarser grades of sand. It is practically devoid of organic matter and contains only a few very fine plant roots. Between depths of 36 and 56 inches or more the material is noncalcareous loose white, or almost white, ash. In size the ash particles range from silt to fine sand. In a few places, and varying greatly in depth and thickness, there is a lime hardpan like that in the Stanfield soils. This layer is very pale-brown or very light brownish-gray mildly calcareous material so firmly cemented that a very hard blow with a shovel or soil hammer is necessary to cut through it. Below the hardpan is pale-brown mildly calcareous friable loam.

For the most part volcanic ash is neither cultivated nor used for growing crops, as it is infertile and in many places contains salts. When salts are removed, organic matter should be supplied and probably some ammonium sulfate or calcium nitrate added. The soil is practically useless at present and in places may be a source of trouble through blowing. The ash is used locally for scouring and cleaning kitchen utensils.

PRODUCTIVITY RATINGS AND LAND CLASSIFICATION

In table 6 the soils of the Umatilla area are listed in alphabetical order and for each are given the estimated average per acre yields—or a range of annual average yields—of the more important crops. Production varies from one part of the area to another, even on the same soil types, because of differences in rainfall, elevation, and temperature, and also because of differences in soil management practices, including those of dry farming, irrigation, and drainage. Where different environmental conditions or management practices affect production on the several areas of a soil type, yields are estimated for each condition, insofar as yield data permit.

Soils at the highest altitudes receive sufficient moisture from rains to produce a crop each year. In somewhat lower lying districts, wheat one year is followed by peas for canning the next year; in the next lower lying belt or district, rainfall is such that one crop is produced every second year following one year of clean summer fallow; and in the districts of lowest elevation rainfall is sufficient for only limited production of grasses and shrubs for grazing. In these lower districts considerable areas have been supplied with irrigation water and a variety of crops are now being produced.

Outside the irrigated districts, the yields represent the productivity of the soil under systems of farming that have been followed for many years. In much of the wheat-producing area and especially in the drier districts, differences in yields are closely associated with the quantity and distribution of rainfall and with other climatic factors that either accelerate or retard plant growth, or tend to preserve moisture in the soil for use by plants, or cause rapid evaporation and loss of moisture from both soil and plants. Many of the dry-farmed soils have a reserve of plant nutrients and are capable of producing yields higher than those tabulated, and during years of unusually heavy rainfall the yields are much above average.

In some places in irrigated sections drainage has been improved and lands once salty or affected by alkali and valuable only for limited production of saltgrass or bluegrass pasture are now being used for a variety of irrigated crops, and the yields are equal to those on similar irrigated soil types where artificial drainage has not been necessary. Some irrigated soils in the central and eastern parts of the area receive sufficient moisture from rains to produce fair yields, but by application of irrigation water substantial increases are obtained.

Cover crops are used in connection with the production of fruit but are not common elsewhere. Soil amendments are not used extensively, and data relating to increased yields as a result of this use are not sufficient for inclusion in table 6, though available data are given in the chapter on land use..

In table 7 the soils are arranged in the approximate order of their productivity and suitability for growing the crops of the area; characterized as to general productivity, workability, water-holding capacity, and erosion hazard; and grouped in five classes as to suitability for farming.

In this classification such geographic and economic factors as location and pattern of distribution of soil types, transportation and marketing facilities, and prices of agricultural products are ignored. Consideration is given only to the ability of the soils to produce crops under the common farming practices; to the ease or feasibility of handling farm machinery and of distributing irrigation water; to the water-holding capacity of the soils, which determines the quantity of water needed and the frequency of application; and to the hazard of destructive erosion on lands cleared for cultivation or heavily grazed.

TABLE 6.—*Estimated acre yields of the principal crops on the soils of the Umatilla area, Oreg.*

Soil and condition	Wheat	Barley	Oats	Peas (canning)	Corn [1] (grain)	Corn [1] (fodder)	Alfalfa [1]	Mixed timothy and clover	Small grains cut for hay	Potatoes [1]	Apples [1]	Prunes [1]	Cherries	Squash [1]	Watermelons [1]	Crested wheatgrass seed	Pasture (acres per animal unit) [2]		Use and management
																	Irrigated	Dry	
	Bu	*Bu.*	*Bu*	*Lb.*	*Bu*	*Tons*	*Tons*	*Tons*	*Tons*	*Bu.*	*Boxes*	*Tons*	*Tons*	*Tons*	*Tons*	*Lb*			
Athena silt loam																			Nearly all used for wheat, much summer-fallowed, but rotation of wheat and peas recently followed in part.
Summer fallow	45																		
Rotation of wheat and peas	40			2,000-3,000															
Burke silt loam, saline phase																	3	60	Grazing.
Caldwell silt loam	50-65						5-8			115	300	6							Fruit, alfalfa, and wheat the principal crops, fruit and alfalfa commonly irrigated, wheat grown on areas with natural subirrigation
Saline phase:																			Pasture, alfalfa, fruit, wheat, and other small grains; yields variable, depending on such factors as salinity, drainage, and irrigation
Better areas	35-45	40	45-50				4-5										1		
Areas with slight accumulation of salts	30	35	40				3				300	6					1		
Caldwell silty clay loam, saline phase																	1		Pasture and alfalfa, yields variable from area to area and from year to year
Better areas							5										1		
Couse silt loam:																			About half in cultivation; one-fourth in pasture, one-fourth in timber.
Summer fallow	35																		
In rotation	18			2,000-2,500				1.5	1.5	[3] 75-100						400			
Ephrata fine sandy loam, irrigated.					30	7	3			140							1-3		Grazing and irrigation farming.
Ephrata loamy sand:																			
Irrigated					30	6.5	2.8			120	240			7	7			40	Do
Poorly drained phase																	2-5		Pasture.
Ephrata sand.																			
Irrigated	28	38			27	5.5	2.5	2		110				7	11			50	Mostly grazing; some irrigation farming.
Shallow phase, irrigated					25	5.5	2			85							2	45-50	Do.
Helmer silt loam	[4] 10-20							1.5	1.5	[3] 70									Largely in timber, subsistence farming on a small area; blackberries and raspberries (2,000 to 2,500 pounds).

Hermiston silt loam:																			
With natural subirrigation	45-50																		Wheat, the principal crop, grown on summer-fallowed land; some grazing in Butter Creek Valley.
East and south of Adams	35																		
West of Adams and Pendleton.	30																		
In Butter Creek Valley	20	35					[6] 2.5											40	
Hermiston very fine sandy loam:																			
Near Adams	35-50						5-6												Wheat, the principal crop, grown on summer-fallowed land.
West of Adams	25-35						[6] 1-3												
McKay silt loam	30																		Nearly all in wheat and summer fallow.
Morrow silt loam	8																		Wheat (with summer fallow), and grazing the chief uses.
Morrow silty clay loam	10																		Do.
Onyx fine sandy loam, irrigated							4.5			170	270	6						20-40	Irrigation farming and grazing.
Onyx loam:																			
Irrigated	35	75			38	11	6	3		200	280	7		10			.5		Mostly cultivated and irrigated.
Dry farming	20-40																		
Onyx loamy fine sand, irrigated					30	8	3											35	Largely used for grazing; some irrigation farming.
Palouse silt loam	45			2,400															Wheat largely grown by summer fallow methods; peas becoming more common.
North and northwest of Thorn Hollow.	60																		
Steeper areas near Weston	40																		
Steep phase																			Best used for grazing.
Pilot Rock silt loam	8-20																		Nearly all used for wheat under summer-fallow system.
Deep phase	20-35																		Do.
Quincy fine sand																		45-50	Grazing.
Hummocky phase																		50-65	Do.
Quincy loamy fine sand	9																	40-50	Grazing, a small acreage in wheat
Shallow phase																		60	Grazing.
Wind-eroded phase																		80	Do.
Ritzville fine sandy loam	10-15																	45	Grazing; some wheat and summer fallow.
Ritzville loamy fine sand	10-15																	50	Grazing and wheat, including summer fallow.
Ritzville silt loam:																			
South and southwest of Umapine.	10-15																		
North and northeast of Nolin.	15-20																	40-50	Nearly all in wheat and summer fallow.
Southwest of Nolin	10																		
Ritzville silt loam, shallow phase	10-15																	55	Grazing and wheat, including summer fallow.
Ritzville very fine sandy loam	10-20						4											25-45	Grazing, wheat, summer fallow, and some irrigation farming.
Shallow phase	10																	55	Used largely for grazing.
Riverwash																			

See footnote at end of table.

TABLE 6.—*Estimated acre yields of the principal crops on the soils of the Umatilla area, Oreg.*—Continued

Soil and condition	Wheat	Barley	Oats	Peas (canning)	Corn [1] (grain)	Corn [1] (fodder)	Alfalfa [1]	Mixed timothy and clover	Small grains cut for hay	Potatoes [1]	Apples [1]	Prunes [1]	Cherries	Squash [1]	Watermelons [1]	Crested wheatgrass seed	Pasture (acres per animal unit) [2] Irrigated	Pasture (acres per animal unit) [2] Dry	Use and management
	Bu.	*Bu*	*Bu.*	*Lb.*	*Bu.*	*Tons*	*Tons*	*Tons*	*Tons*	*Bu.*	*Boxes*	*Tons*	*Tons*	*Tons*	*Tons*	*Lb.*			
Rough broken and stony land																		40–200	Grazing
Timbered phase																		200	Timber, some grazing.
Rupert coarse sand, irrigated					20	4 5	1.5			85								65	Grazing, some irrigation farming.
Rupert sand, irrigated					25	5.5	2 5			100				6.5				60	Grazing and irrigation farming.
Sagemoor silt loam							3											55	Do.
Scabland																		45–50	Grazing
Shallow stony soils																		30–40	Do.
Snow silt loam	25–60						[5] 2–8				250	5–6	3–3 5						Nearly all in wheat except where irrigated, yields variable from area to area because of local conditions, including water available for irrigation.
Stanfield fine sand																	1		Largely in pasture, alfalfa and barley the principal crops on reclaimed areas.
Reclaimed areas		25–40					2–4												
Stanfield very fine sandy loam																	1		Largely in pasture.
Thatuna silty clay loam																			
Rotation	20–25			2,400						[3] 120									Mostly in wheat, peas, and potatoes.
Summer fallow	50–55																		
Poorly drained phase																			Largely in pasture.
Better drained areas	15–20		40	2,400						[3] 100									
Umapine very fine sandy loam																		1	Do.
Reclaimed areas, irrigated	45	60					3 5				220								
Underwood stony loam																		100–200	Timber and grazing.
Volcanic ash																			Mostly wasteland; some grazing.
Waha silt loam	20–25			1,500–2,000															Mostly in wheat under summer fallow or in rotation with peas.
Deep phase	45			2,400															Do.
Waha silty clay loam	10–35			2,000															Do.
In extreme southwestern part.	18																		Do.
Deep phase	35			2,200															Do
Waha stony silt loam																		30	Grazing.

Walla Walla silt loam:																			
Eastern, or upper, areas	40-45	65		2,500												500			Nearly all in wheat and summer fallow; some peas, barley, and crested wheatgrass seed also grown.
Western areas	30-40																		
Light-textured phase	30	40							2										Nearly all in wheat and summer fallow.
Shallow phase	10-25															170-300			Nearly all in wheat and summer fallow; yields variable, depending in part on depth of soil above bedrock and on rainfall.
Walla Walla very fine sandy loam.	20-25																		Nearly all in wheat and summer fallow.
Winchester sand																			Value for grazing very low.
Yakima cobbly loam, irrigated							2-3				235	4.5	2		7				Fruits, truck crops, and alfalfa.
Yakima gravelly loam, irrigated							2-4				250	5	2.5		9				Fruits, truck crops, alfalfa, and grazing.
Yakima loam:																			
Irrigated							[4] 2-5				250	5.5							Fruits, truck crops, alfalfa, and wheat.
Dry farming	15-25																		Do.
Yakima silt loam:																			
Irrigated							[5] 2-5				250	5	2						Do.
Dry farming	15-30																		Do.

[1] The yields for these crops are obtained under irrigation.
[2] An animal unit is the equivalent of a mature horse, cow, or steer, or 5 hogs, or 7 sheep or goats.
[3] This yield is not obtained under irrigation, and is an exception to footnote 1.
[4] These yields apply to relatively "new land."
[5] Yields are restricted by a limited amount of available irrigation water.

TABLE 7.—*Classification of the soils of the Umatilla area, Oreg., as to their suitability for the production of crops* [1]

Land classification and soil	General productivity [2]		Workability [3]	Water-holding capacity [4]	Erosion hazard [5]
	Under dry farming	Under irrigation			
FIRST-CLASS SOILS (very well suited to the production of crops):					
Caldwell silt loam	High	High	Easy	High	Slight.
Snow silt loam	do	do	do	do	Do.
Hermiston silt loam	Medium to high [6]	do	do	do	Do.
Hermiston very fine sandy loam	do [6]	do	do	Medium	Do.
Onyx loam	do	do	do	High	Do.
Thatuna silty clay loam	High		Fairly easy	do	Moderate.
Athena silt loam	do		Easy	do	Do
Walla Walla silt loam	do		do	do	Slight to moderate
Palouse silt loam	do		Easy to difficult [7]	do	Moderate to great.[7]
Waha silt loam, deep phase	do		do	do	Do [7]
Waha silty clay loam, deep phase	do		do	do	Do.[7]
SECOND-CLASS SOILS (well suited to the production of crops):					
Caldwell silt loam, saline phase		Medium to high [8]	Easy	do	None.
Caldwell silty clay loam, saline phase		do [8]	Fairly easy	do	Do.
Onyx fine sandy loam		do [8]	Easy	Medium	Slight.
McKay silt loam	Medium		do	Medium to high	Do.
Couse silt loam	do		do	do	Moderate.
Walla Walla silt loam, light-textured phase	do		do	High	Slight to moderate.
Yakima silt loam	do	Medium to high	do	Medium to low	Slight.
Yakima loam	do	do	do	do	Do.
Pilot Rock silt loam, deep phase	do		do	Medium	Moderate
Waha silt loam	do		Easy to difficult [7]	do	Moderate to great.[7]
Waha silty clay loam	do [6]		do [7]	do	Do.[7]
THIRD-CLASS SOILS (moderately well suited to the production of crops).					
Yakima gravelly loam	Very low	Medium to high	Difficult	Low	Slight or none.
Yakima cobbly loam	do	do	Very difficult	do	Do
Walla Walla very fine sandy loam	Medium to low [6]		Easy	Medium	Slight to moderate
Walla Walla silt loam, shallow phase	do		do	Medium to low	Do.
Ritzville silt loam	do [6]	Medium to high	do	High	Do.
Ritzville very fine sandy loam	do [6]	do	do	Medium	Do.
Sagemoor silt loam		do	do	High	Do.
Pilot Rock silt loam	Medium to low		do	Medium to low	Do.
Helmer silt loam	do		do	High	Slight.
Ephrata fine sandy loam		Medium to high	do	Medium to low	Do.
Umapine very fine sandy loam		do [8]	do	Medium	Do.
Thatuna silty clay loam, poorly drained phase	Medium to low [9]		Easy to difficult [9]	High	Do.
Onyx loamy fine sand		Medium	Easy	Low	Moderate.
Ephrata loamy sand		do	do	do	Do.
Ritzville fine sandy loam	Low	do	do	Medium	Do
Ritzville loamy fine sand	do	do	do	do	Moderate to great

Fourth-class soils (poorly suited to the production of crops):					
Ritzville silt loam, shallow phase	do [6]		do	Medium to low	Slight to moderate
Ritzville very fine sandy loam, shallow phase	do [6]		do	do	Do.
Morrow silty clay loam	do		Fairly easy	do	Do.
Morrow silt loam	do		do	do	Do.
Quincy loamy fine sand	do	Medium	Easy	do	Moderate to great.
Ephrata sand	do	Medium to low	do	Low	Do.
Shallow phase	do	do	do	do	Do.
Rupert sand		do	do	do	Medium to great.
Rupert coarse sand		do	do	do	Do.
Stanfield very fine sandy loam		do [8]	do	Medium	Slight
Stanfield fine sand		do [8]	do	Medium to low	Slight to moderate.
Quincy fine sand		do	do	do	Moderate to great
Quincy loamy fine sand, shallow phase		do	do	Low	Do.
Quincy fine sand, hummocky phase		do	do	do	Great
Fifth-class soils (unsuited to the production of crops):					
Ephrata loamy sand, poorly drained phase		Low	Difficult	High	None.
Burke silt loam, saline phase			Moderately difficult	Moderate	Slight.
Quincy loamy fine sand, wind-eroded phase			Difficult	Low	Great
Palouse silt loam, steep phase			Very difficult	High	Do.
Waha stony silt loam			do	Low	Slight to great.
Shallow stony soils			do	do	Do.
Scabland			do	do	Do.
Rough broken and stony land			do	do	Great.
Timbered phase			do	do	Do.
Underwood stony loam			do	do	Slight to great.
Riverwash			do	do	Great.
Winchester sand			Difficult	do	Do.
Volcanic ash			do	do	Do.

[1] This classification is merely a rough grouping of soils as to their suitability for the production of crops under prevailing farming practices. It does not take into consideration economic factors or the location and the pattern of the distribution of soil types. Local variations in soil, climate, relief, drainage, and salt concentration result in differences in productivity and suitability for use within a single soil type.

[2] General productivity refers to the capacity of the soil to produce the common crops of the region under the prevailing farming practices. In a number of instances land not now under irrigation is given a rating as to its probable productivity if and when irrigated.

[3] The term "workability" as here used refers to the relative amount of labor required to till the land and the relative ease of handling farm machinery.

[4] The water-holding capacity of the soil determines to considerable extent the productivity of dry-farmed land, the frequency of irrigation, and the quantity of water used on irrigated land.

[5] Erosion hazard means the susceptibility of the soil to erosion if and when cultivated or heavily grazed. It refers both to wind drifting and to erosion by water.

[6] These soils occur under a considerable range of precipitation, the soils of the areas receiving higher rainfall are considerably more productive under dry farming than are the soils of the drier areas.

[7] The steep slopes of some areas of these soil types makes tillage, handling of machinery, and control of erosion difficult. Such areas belong in a lower class.

[8] The productivity and workability of these soils depends to considerable extent on local drainage conditions.

Note. Blank spaces indicate that the soil is not used under dry farming or under irrigation, as the case may be.

Because of limitations in the detail that may be shown on a soil map and the unavoidable inclusion of considerable variations within soil types as mapped, these ratings should not be considered as applying strictly to all areas of a soil type. Poor drainage conditions and concentrations of salts, largely developed by seepage after the land is brought under irrigation, still further complicate the classification. The poorly drained or salty areas are generally less productive than those better drained. The salt concentrations are shown on the map by red boundaries and symbols. Areas of moderate concentration are generally poorer than those comparatively salt free, whereas those having strong salt concentrations are unfit for cultivation unless reclaimed by special measures. Steeply sloping areas of some of the soil types belong in a lower class than typical areas.

LAND USE AND SOIL MANAGEMENT

About 23 square miles, or 14,720 acres, of land sufficiently smooth to permit cultivation is now being used mainly for the production of timber and is of low value for grazing. Approximately 16,640 acres now growing timber is too steep or rocky to be cultivated, and most of it is probably more valuable for that use than for cultivated crops. In addition to the forested areas there are about 600,000 acres of plowable land, of which about 80 percent is normally used for wheat. From the viewpoint of financial returns, wheat is the best crop that can be produced on most of these soils.

It is apparent that large acreages are becoming less productive. This is caused in part by the loss of the surface soil by erosion, by blowing in the drier parts of the area, and in the areas where rainfall is higher, by both blowing and runoff, especially the latter. Under the present farming practices, however, there is little indication that the cultivated soils are becoming less productive except where subject to erosion. In past years and to some extent at present, farmers burn the wheat stubble rather than return it to the soil. In the sections of most fertile soil, unless erosion has occurred because of loss of protective covering, yields have not diminished materially where the straw and stubble have been burned, but on the less fertile soils, west and northwest of Pendleton, yields have decreased where stubble has been continually burned. Lower yields in all sections will eventually result if the stubble is not preserved. The decreases up to the present have been slight because of the abundance of organic residue that has been incorporated in the soil from grass growth previous to the settlement and cultivation of the land.

The results of experiments show that the use of sodium nitrate applied at the seeding time of winter wheat gives the highest yields with continuous cropping. Although the soil upon which the wheat is grown has a fair quantity of organic matter and nitrogen, addition of nitrates appears beneficial. This is probably partly due directly to the fertilizing effect of the nitrate added and in part to its effect upon decomposition of straw and the carbon-nitrogen ratio, or balance. The addition of manure gives marked increases in yields. Burning the stubble does not lower yields materially, but this is probebly due to the fact that the soil contains a moderate quantity of organic matter. If the tests are continued over a long period of years, yields undoubtedly will be reduced on plots where stubble is burned.

Wheat yields are probably declining slightly on many farms, chiefly in the heavier yielding sections where extensive water erosion has begun noticeably to affect soil fertility. Most of the wheatlands in the Columbia Basin have been farmed less than 45 years. Any general reduction in yield because of erosion or fertility depletion has apparently been offset by improvements both in farming methods and in varieties produced, as no downward trend in yield is noticeable from available data.

A typical wheat farm consists of large tracts of rolling cropland separated from each other by canyons, steep slopes, or rocky outcrops that are generally used for pasture. The native pasture is generally used to carry the livestock from the time the stubble land is plowed in spring until new stubble pasture is available in fall. Sometimes it is supplemented by plantings of wheat or rye. In that part of the area where 10 percent of the land is in pasture, there is an average of 17 animal units—cattle, sheep, and horses—to the farm—the number being primarily controlled by the stubble pasture available.

The suitability of the different soils or kinds of land to the growth of the different crops is discussed in the section on soils and crops. It is probable that increases will be made in the acreages of tomatoes, asparagus, and other truck crops that may be packed by canneries at Milton and Pendleton. Owing to the establishment of canneries, the area used for growing green peas for canning probably will increase.

CONTROL OF INSECT PESTS, DISEASES, AND WEEDS [7]

Smut is the chief disease affecting wheat. It is controlled by the use of 2 or 3 ounces of copper carbonate to the bushel of seed wheat. Experiments being made to obtain information relating to smut-resistant varieties indicated that Rex, Oro, and Rio are the most smut-resistant and that Albit has some resistance but shatters badly.

The weevil is a serious pest in growing peas. Rotenone, a dust, is applied at the rate of about 20 pounds to the acre, usually about three times a season, though additional applications are necessary when rains wash it from the plants. Rotenone is usually applied with a lateral duster to a strip about 300 feet wide around the outer margins of the field, because the weevils enter from roadsides or fence rows. They feed principally on the pollen, and the dust kills most of them before they get far into the fields. Rotenone also kills aphids, which may be serious during warm moist seasons, but generally the growing season is dry.

The alfalfa weevil occurs in many irrigated alfalfa districts of the Western States but has not been found in the Umatilla area. Alfalfa wilt, a bacterial disease, has been identified near Stanfield and in the upper part of Butter Creek Valley.

Although for more than 10 years some fields of alfalfa have been and are still producing good yields, many farmers complain that stands do not thrive more than about 3 or 4 years. In some places

[7] Since the report was written (1937) many improvements in pest and weed control have been developed. The Oregon State Agricultural Experiment Station can supply information on the most recent methods.

this is probably because of alfalfa wilt, though in others on coarse-textured soils the declining yields probably result from decreased fertility, increases in weed infestations, use of tender varieties, and winterkilling.

The use of Ladak alfalfa, a more hardy and disease-resistant variety, is recommended. On the coarse-textured soils especially, alfalfa should be left only 4 to 6 years, depending somewhat upon the infestation of bluegrass or other plants. Corn should follow alfalfa for 2 years, which, in turn, should be followed by a nurse crop of barley, rye, or wheat at the time alfalfa is reseeded. This rotation will serve to control weeds and disease and result in better yields.

Several sprays and dusts are used in connection with the production of fruit and of potatoes, melons, and other vegetables. Discussion of insect pests and diseases and recommendations relating to control measures are available at the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, Washington, D. C., and State bulletins are available at Oregon State College, Corvallis, Oreg., the State College of Washington, Pullman, Wash., and the College of Agriculture, Moscow, Idaho.

The distribution and infestations of noxious weeds and the importance of control or eradication methods are of sufficient importance to justify the cooperation of all farmers in the area. According to the county agent, morning-glory, or bindweed, occupies 3,460 acres in Umatilla County, whitetop 375 acres, Russian knapweed 75 acres, and woolly milkweed 175 acres. Quackgrass and other coarse grasses are not so widespread as other perennial weeds. Weeds that are noxious but do not so seriously interfere with the growth of commercial crops include Russian-thistle, tarweed, Jim Hill mustard, peppergrass, and sandbur. Others of less importance are dock, rushes, puncturevine, wild carrot, wild parsnip, dogfennel, and ragweed.

The control of the morning-glory, the chief or most widespread perennial, is rather difficult owing to its wide distribution, the expense of treatment, and the necessity of enlisting cooperation of farmers, renters, owners of highway right-of-ways, railways, and others interested in land, crops, and weeds. Clean cultivation, allowing no green growth above the surface, should exterminate this or any plant if continued for a period of 3 to 5 years. Because of the unusual abundance of potential plant food stored in the roots of the morning-glory, it is doubtful whether 3 years' clean cultivation will exterminate the plant. Use of sodium chlorate, though expensive, is probably more effective than clean cultivation, though it produces harmful effects on the soil. Pentox, an arsenical preparation, which has been used rather extensively recently, kills leaves of the plant and goes down into the ground through the stems, and appears to have killed roots as much as 3 feet or more below the surface. It is cheaper to apply than sodium chlorate, but the history of the use of other arsenical sprays indicates that they have been less effective.

In addition to clean cultivation and the use of sprays, smother crops are used as measures of control. The Russian-thistle is controlled in cultivated areas where fall seeding and clean cultivation by summer fallow are practiced. Where spring wheat is grown continuously, the Russian-thistle infestation is likely to become serious.

Tarweed, mustard, and peppergrass are held in check by spring-seeded wheat. Where wheat is generally seeded in fall, the rate of seeding is often sufficient to produce a stand dense enough to smother out these and other annual weeds. Control of weeds in irrigated sections, where whitetop, quackgrass, and other coarse grasses are most prevalent, includes the use of sprays on perennials, cultivation, cutting weeds from row crops, and rotation of crops.

CHEMICAL CHARACTERISTICS OF SOILS

The results of the chemical analyses of soils in the Umatilla area are given in table 8.

The Helmer soils, which are the heaviest timbered soils in the Umatilla area and generally lie at the highest elevations, are also the most acid. Couse silt loam, which also is fairly acid and usually merges

TABLE 8.—*Chemical composition, organic-matter content, and reaction (pH) of certain soils in the Umatilla area, Oreg.*[1]

Soil type and sample No.	Depth	K_2O	CaO	MgO	S	P	P_2O_5	N	Organic matter	pH
Helmer silt loam	*In.*	*Pct*	*Pct*	*Pct*	*Pct.*	*Pct.*	*Pct*	*Pct.*	*Pct.*	
19079	0- 8	1.95	2 02	0 78	0 008	0.175	0 401	0.098	1.74	6 0
19080	8-18	1 87	1 93	77	.007	179	410	.075	1.26	5 7
19081	18-28	2.41	1.68	.62	.002	.087	200	.022	.96	5 3
Couse silt loam										
19061	0- 5	1 83	2 18	1.15	016	125	286	.133	3 34	6 3
19062	5-12	1.80	2 09	1.09	.021	083	.191	.095	1.80	5.5
19063	12-22	1 80	2.04	1.18	.010	.068	.155	.079	1.23	5.4
Thatuna silty clay loam										
19064	0- 8	1.84	2 20	1 13	.018	.128	293	.205	5.17	5 5
19065	8-27	1.90	2.11	1 13	.013	122	280	118	2 33	5 7
19066	27-42	2.13	2 04	1 05	.013	069	.157	067	.99	5.9
Palouse silt loam										
19116	0- 4	1 98	2.51	1 34	020	092	211	.178	4.00	6.6
19118	4-21	1.74	2 30	1 03	004	083	190	.191	4.09	6 0
19119	21-24	1 71	2 43	97	.030	083	189	190	4.11	5 9
19120	24-31	1 96	2.39	1 02	029	.073	.166	.166	3.50	6.1
Walla Walla silt loam										
19146	0- 8	1 84	2.20	26	010	068	155	.098	2.18	6 3
19147	8-15	2 08	2.25	41	.010	072	.164	090	1.68	6 6
19148	15-24	2 00	2.24	36	021	.101	231	069	1.05	7 0
19149	24-36	2.08	2 83	1 71	.003	.090	.207	052	.78	7.6
Walla Walla silt loam, light-textured phase										
19070	0- 8	1.46	2 14	.43	012	.105	.240	.081	1 85	6.1
19071	8-21	1 96	2 72	.40	007	109	250	.077	1 45	6.9
19072	21-44	1.93	1 86	.54	.007	.116	.265	.049	.96	7 6
Walla Walla very fine sandy loam										
19136	0- 8	2 00	3 02	1.66	.012	.090	.206	067	1 28	7 0
19137	8-21	2.08	3 29	1.86	013	089	.203	059	1 09	7 3
19138	21-36	2 14	3.12	1 76	016	100	.229	.047	84	8 0
Ritzville silt loam										
19058	0- 8	2 13	2 67	1 44	004	089	.203	.055	.97	6 6
19059	8-19	2 05	2 74	1 52	009	090	.207	.054	.76	7 2
19060	19-33	2.04	2.86	1 60	.014	097	.222	.049	.94	7 6
Ritzville very fine sandy loam										
19055	0- 8	2.12	2 91	1 05	004	097	222	049	.95	6 9
19056	8-23	2 18	3.14	1.74	.002	100	.229	.042	.89	7 1
19057	23-35	2 08	3.12	1 34	.005	.105	.240	.038	1.00	7.5
Ritzville fine sandy loam										
19151	0- 8	1 99	2 97	1.44	018	.099	.226	.066	1 22	7.3
19153	8-30	2.12	3 04	.55	.004	.057	130	.041	.73	7.5
Pilot Rock silt loam, deep phase										
19052	0- 8	1 75	2 65	98	018	073	167	.092	2 11	6 3
19053	10-17	1 63	2 70	.93	018	068	.156	067	1 39	6.5
19054	17-24	1.98	2 73	1 06	008	.072	.165	057	.99	7.6
Pilot Rock silt loam										
19067	0- 8	1 37	2 39	.64	.009	.083	.190	.088	1 82	7.1
19068	8-19	1.54	2 06	.62	.009	081	.186	.074	1.70	7.0
19069	19-30	1.65	2 66	1.27	.009	.084	.193	.061	1.15	7.3

[1] Determinations made by Oregon Agricultural Experiment Station.

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TABLE 8.—*Chemical composition, organic-matter content, and reaction (pH) of certain soils in the Umatilla area, Oreg.*[1]—Continued

Soil type and sample No.	Depth	K_2O	CaO	MgO	S	P	P_2O_5	N	Organic matter	pH
McKay silt loam	*In.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct*	*Pct*	*Pct.*	*Pct*	
19122	0–10	1 75	2 11	0 34	0 019	0 042	0 096	0 135	2 68	6.0
19123	10–13	1 64	2 18	30	.016	028	.063	.113	2 73	6 8
19124	13–19	1 69	2 18	40	016	.035	.079	089	1 85	7.2
19125	19–27	1.61	1 97	.59	.017	.033	.076	.084	1 32	7 2
Ephrata loamy sand										
19073	0– 8	2 00	2 81	51	.018	.116	265	033	84	7.3
19074	8–21	1.94	3 01	49	010	.120	275	026	83	7 5
19075	21–35	2 07	3 09	92	011	124	284	021	52	7.8
Rupert coarse sand										
19076	0– 8	2 00	3 57	1 61	.026	.134	307	139	3 26	7 7
19077	8–21	1 92	3 78	1 63	018	.130	297	082	1.65	6 7
19078	21–38	1.81	4 87	1 20	.013	.131	.299	050	1 09	6.7
Ephrata sand										
19171	0– 8	1 96	3 22	64	004	085	.194	042	80	7 3
19172	8–36	1 94	3.14	1 55	.001	.175	401	028	51	7 4
Onyx loam										
19162	0–14	1 99	2 83	.73	014	069	159	105	2 07	7 5
19163	14–40	1 82	2 84	65	.021	.119	272	055	1.21	7.7
Onyx fine sandy loam										
19131	0– 8	2 19	1 76	1 61	002	.082	188	073	1 52	7 9
19134	8–72	2 00	3 44	1 83	005	076	175	034	83	9 6
Hermiston very fine sandy loam										
19142	0–13	2 01	2 52	95	016	073	.166	079	1 96	7 4
19143	13–34	2 24	2 84	92	029	.061	.140	065	1 63	9 7
Caldwell silt loam, saline phase										
19167	0–18	1 63	7 94	1 60	026	061	140	.180	2 77	9 8
19168	18–24	1 40	11 38	1 60	023	.122	279	152	1 92	8 4
19169	24–60	1 48	4 47	65	007	102	.233	050	.75	8.2
Sagemore silt loam										
19128	0–13	2 28	3 05	44	008	.008	.201	056	.90	7 9
19130	13–38	2 31	6 03	1 81	017	086	.196	035	.62	8 3
Hermiston silt loam										
19157	0–12	1 89	3 22	1.41	.009	065	.149	137	2 91	7 9
19158	12–20	1 74	3 79	1.58	.001	.070	.160	057	1 31	8 6
19159	20–44	1.77	3 99	.60	011	.074	170	043	.98	8.6

[1] Determinations made by Oregon Agricultural Experiment Station.

with the Helmer soils, is in the pine-covered districts and lies at slightly lower elevations, where the rainfall is somewhat less. These two soils are not highly acid but may respond to applications of lime, especially if alfalfa, clover, grains, and other plants that require appreciable quantities of calcium are grown.

In regular succession, each soil occurring at a lower elevation and in an area of lower rainfall is decreasingly acid. The subsoils of Sagemoor silt loam, Onyx fine sandy loam, Hermiston silt loam, and Hermiston very fine sandy loam, and both surface soil and subsoil of Caldwell silt loam, saline phase, are so highly alkaline that improved structure and physical condition should result from any practice that will reduce the degree of alkalinity without injuring the soil.

Most cultivated soils of the area are of desirable reaction for the production of the crops now being grown, and although very slight acidity has developed in the upper layer of most soils used for wheat, the reaction of the subsoil material is such that calcium should be available for use by plants.

The raw organic accumulation on top of the Helmer and the Couse soils was not analyzed, but the organic matter and the nitrogen incorporated in the surface soils are low. Soils in the higher elevations, immediately west of the timbered areas, where the annual precipitation is high, have the highest content of organic matter, especially the surface soils of Thatuna silty clay loam and Palouse silt loam. Most of the soils of the smooth to rolling plains described as medium- to dark-colored are moderate in content of organic matter, and most of those in the light-colored groups are low in organic matter. Moderate quantities occur in some of the light-colored soils, generally not well incorporated, but existing as raw material. Total nitrogen parallels content of organic matter.

Before tests for soluble phosphates were more generally used, a content of 0.09 percent of phosphorus was considered favorable unless the soil was very acid and contained considerable iron or aluminum, which united with and rendered the phosphorus insoluble. Phosphorus is also somewhat insoluble in soils, like the Sagemoor silt loam, which contain excessive quantities of calcium carbonate. Most of the soils in the Umatilla area are not highly acid and do not carry excessive calcium carbonate in the upper layers. Most of those tested contains sufficient phosphorus. Several soil samples taken from fields that have produced wheat for a period of more than 40 years show a slight reduction of phosphorus in the 4-inch surface layer or, in places, in the 8-inch layer. The analyses in table 9 indicate that McKay silt loam is lacking in phosphorus, but according to several field tests with the Bray method, not in soluble phosphates.

Tests for soluble phosphates by use of the Bray method were made of nearly all of the slightly acid soils of the area, and though the upper 8 to 15 inches in many fields of Ritzville and Walla Walla soils show some depletion, the subsurface in practically all samples tested contained considerable available phosphorus. In Walla Walla silt loam and in the Palouse, Waha, Underwood, Thatuna, Couse, and Helmer soils, field tests indicate a fair quantity of soluble phosphates.

According to data in table 8 the content of potassium is fair in all the soils analyzed.

A percentage of 0.02 of sulfur, which is equal to about 400 pounds an acre to plow depth, is generally considered average. Many of the soils analyzed, such as those of the Ritzville series, contain much less than 0.02 percent, so it is probable that yields of many crops may be increased following applications of that element. As the analysis of total sulfur, like that of total phosphorus, does not always correlate with available sulfates in the soil, the information included in the table should not be used as an exact criterion.

The supply of calcium appears adequate in all but the forested soils of the Helmer and Couse series, and it is very probable that on these soils applications of limestone would increase the yields of alfalfa, clover, or other plants that require neutral or slightly alkaline conditions.

The content of magnesium is favorable in all the soils tested.

WATER CONTROL ON THE LAND

Water control on the land refers to all measures used to retard excessive runoff of rainfall and of water from melting snow and to maintain favorable moisture conditions by summer fallowing, irrigation, or drainage. Only in the comparatively small farming section in the Blue Mountains is the annual rainfall sufficient to produce satisfactory crops each year. In the greater part of the area the rainfall of 2 years is used, by means of the practice of summer fallowing, to produce a single season's crop of wheat. In the valleys of the Walla Walla and Umatilla Rivers and some of their tributaries and on the Columbia River terraces near Hermiston and Umatilla, irrigation is practiced to produce a rather wide variety of crops. In the irrigated sections drainage is essential in places to dispose of excess water, to keep the water table low enough for crops to be produced successfully, and to make possible the flushing out of soluble salts (alkali).

CONTROL OF RUNOFF AND EROSION

Much of the precipitation in the Umatilla area comes in gentle rains that do not cause much runoff. Occasional heavy rains, however, and rapidly melting snows at times produce considerable runoff, especially on the steeper slopes. This runoff wastes water needed by crops and grasses and results in soil erosion on land that is not protected by a thick cover of vegetation.

On land that is very steep, tillage, especially clean summer fallow, and overgrazing are harmful, and excessive runoff and erosion can be prevented only by maintaining or restoring grasses or other vegetal cover. Crested wheatgrass probably will prove useful in reestablishing a grass cover.

On land that is not so steep or that for other reasons is less subject to rapid runoff and erosion, effective control may be accomplished by the maintenance of a trashy or cloddy fallow, which enables the soil to absorb most of the water that falls upon it. Strip cropping has not been practiced to any great extent, but doubtless it would prove effective in some localities.

IRRIGATION

In a large part of the Umatilla area irrigation is essential to the production of crops other than wheat, and with its aid these may be grown in wide variety.

Grain was grown by irrigation at the junction of Pine and Dry Creeks about 1869 or 1870. In the Walla Walla, Umatilla, and Butter Creek Valleys and in the vicinity of Hermiston irrigation has been practiced, and the area irrigated has been increased by development of additional land from about 1870 to the present. Irrigation water is applied on comparatively smooth low-lying lands in the larger valleys and in most of the smaller valleys where stream flow is sufficient. Water rights on some of the land near Umatilla date back to 1860, but most of them from about 1870 to 1910. Development has been furthered by irrigation districts, mutual irrigation companies, and individuals who maintain private ditches or wells.

In the drainage basin of the Umatilla River many short private ditches are used to carry water diverted from the smaller creeks. The normal flow of the Umatilla River is entirely diverted and is used directly for irrigation or stored in Cold Springs Reservoir for use later in the season. Several miles of canals that vary in capacity and length are operated by different irrigation organizations. Cold Springs Reservoir, which covers 1,500 acres when full, has a storage capacity of 50,000 acre-feet. This water is used to irrigate about

6,500 acres around Hermiston. The McKay Dam, on McKay Creek, impounds approximately 73,000 acre-feet, and when the reservoir is filled the lake covers approximately 1,000 acres. This water is used to irrigate land in the Umatilla Valley, principally below Echo and as far as the northwest corner of the county. Several thousand acres in Butter Creek Valley, in Umatilla Valley, in the valley of Birch Creek and its environs, and in the McKay Creek, Wildhorse, and Tutuilla Creek Valleys or lands closely adjacent to these valleys, are irrigated.

The flow of Butter Creek and of many of the smaller streams is not continuous or sufficient to supply much water during the latter part of the usual irrigation season, but flood or runoff water is applied on the land during periods when available. Irrigation usually begins in Butter Creek Valley about January 1 and continues until late in May or early in June. The annual runoff in 1934 was 3,413 acre-feet, in 1922 it was 27,700, and the average from 1921 to 1936, inclusive, excepting 1925, was 13,903 acre-feet. Approximately 5,000 acres in Butter Creek Valley have water rights. As there are large fluctuations in the quantity of runoff and as water is available during the earlier part of the growing season only, water must be applied when it is available and therefore it is usually stored in the soil previous to the growing season. The number of cuttings of alfalfa is less than from other irrigated soils where there is water for irrigation later in the season.

Availability of water for irrigation in several other creek valleys is similar to that in Butter Creek Valley. Other districts where irrigation is extensive are in Walla Walla Valley and in smaller valleys adjacent to streams that flow into the Walla Walla River. Extensive areas are irrigated from the Walla Walla River and from Spring Branch, and others in Pine Creek and Dry Creek Valleys. The North Fork of the Walla Walla River is usually too low to furnish water for irrigation after July 1. The South Fork, however, generally delivers about 100 second-feet throughout the season and much more during periods of heavy runoff in spring. Pine and Dry Creeks flow intermittently .

In the Walla Walla Valley and in the valleys of streams tributary to the Walla Walla River, as in Butter Creek Valley and in practically all places where the stream flow is not sufficient to supply water during the entire growing season, the practice is to store water in the soil by irrigation prior to the growing season and whenever it is available. Such storage is limited, especially on shallow, sandy, and gravelly soils of low water-holding capacity. In some places water is not available after the first cutting of alfalfa. On deep soils of loam or heavier texture alfalfa is irrigated once to each cutting, and in many places twice, where the water table is far below the surface. On soils of sandy loam texture, the practice during the growing season is to apply water about once every 2 weeks on alfalfa and grain and in orchards. In the coarser textured sandy soils and the soils of excessively leachy character, including the shallow gravelly Yakima soils of the Walla Walla Valley, the practice is to irrigate once each week or oftener for afalfa, corn, grain, and orchard crops and two or three times a week for strawberries, tomatoes, garden vegetables, and others with shallow roots. Where the application is made several times a week, each irrigation period is 2 to 4 hours; where it is once a week, the period is 8 to 12 hours. Where application is made at longer intervals, the length of time depends upon the availability of water, the acreage, the water-holding capacity of the soil, and the needs of the crops. In many places a continuous flow is provided to each irrigator and is rotated over the different parts of his farm.

Fruit trees, vegetables, and row crops are irrigated by use of furrows; alfalfa in the Walla Walla Valley, as in most of the area, is irrigated by use of corrugations, although most alfalfa on the comparatively flat lands west of Stanfield and Echo is irrigated by use of borders and basins. In Butter Creek Valley about 200 acres have been bordered, about 300 acres are irrigated by use of corrugations, and the rest, or about 4,500 acres, is flooded. Where the land is uneven or has much slope, the corrugation system is preferred for alfalfa, grain, and similar crops.

The irrigation requirement is not the same for all crops, and because of differences in texture, permeability, depth, and water-holding capacity of soils, both the number of irrigations and the quantity of water used each season varies in different places. The water applied for alfalfa, where the ground-water level is not close enough to provide subirrigation, ranges from about 2 acre-feet on the loam and silt loam soils to as much as 10 acre-feet or more on leachy sandy or gravelly soils. In places where the ground water is within reach of the roots, only very small quantities of water are applied.

In comparatively flat or in troughlike valleys and especially southwest of Stanfield and in many districts near Umapine, the level of the ground water is high and no irrigation is required. In many places, however, owing to an excess of water in the soils, salts have accumulated on or near the surface in such quantities that saltgrass, which is used only for pasture, now forms the principal cover.

Seepage and waste water and the runoff caused by using a large head of water are used on succeeding lower lying areas. In the Walla Walla Valley, principally in the orchard districts, supplemental water is obtained by pumping from an underground supply. In that section there are approximately 300 wells in which water is pumped from the lower gravel strata for irrigation and in addition, water appears at the surface in many springs, forced there by underlying fine-textured sediments.

DRAINAGE AND ALKALI

In arid sections, most soils are comparatively high in soluble salts, which in places are highly concentrated. A large part of the salts set free by the decomposition of soil minerals remains in all but the most porous soils, as the rainfall is too light and evaporation too high to allow deep penetration of water and consequent leaching. Salt concentrations that are strong enough to be toxic to plants, however, commonly develop only in lower areas where drainage is poor. In such places evaporation results in a gradual accumulation of salts. Where the water table is high, water rises through the soil by capillarity and leaves the salts at the level where it evaporates. These salts are readily dissolved and moved in solution to any part of the soil profile, and, especially under irrigation, they are constantly shifted.

Toxic soluble salt concentrations are commonly spoken of as "alkali." In its general or popular application, this term includes both the neutral, or saline, and the alkaline salts. The former are often called white alkali because they form white salt crusts, and the latter are called black alkali because in places they form dark crusts stained by organic matter. The saline salts consist largely of the neutral salts of sodium, predominantly the chloride and sulfate; whereas the black alkali, or alkaline salts, are usually expressed as sodium carbonate.

In the Umatilla area readily soluble salts have been leached almost entirely from the soils in districts where the annual rainfall averages 20 inches or more. The same is true under much lower rainfall where the soil and substrata are deep, permeable, and well drained. Under poor drainage conditions an accumulation of salts is apparent in either the surface or subsoil of such soils as the Hermiston and Stanfield and Caldwell silt loam, saline phase. In localities of still lower rainfall, the increase of alkali and other salts generally becomes more noticeable, and in many places it seriously affects crop production on the Stanfield, Umapine, and Hermiston soils, the Caldwell silt loam, saline phase, the Burke silt loam, saline phase, and to some extent on the Onyx soils.

Plant tolerance of salts depends on many factors, including kind of plant and stage of growth, kind and concentration of salts and their location in the soil profile, texture of soil, moisture conditions, temperature, evaporation, and the salt content of irrigation water. A concentration of salts in the lower part of the subsoil may not interfere with the growing of shallow-rooted crops, as small grains and corn, whereas it will interfere with alfalfa, fruit trees, and other deep-rooted plants. Sprouting seeds and young seedlings are much more susceptible to injury than are well-established plants. A given quantity of soluble salt is more toxic in a sandy soil than in a heavy-textured soil, as the soil solution is more concentrated in the former. Salts produce more serious effects when the soils are comparatively dry and the weather hot and dry. The use of salty irrigation water may add to the toxic effect of a soil solution already high in salts, but this depends on the relative salt concentrations in the two, for water that is slightly salty will dilute a concentrated soil solution.

The chemical and physical properties of the soils should be given first consideration in the problems of reclamation. It is more or less impracticable to reclaim soils that have been badly puddled by alkali, especially soils that have a heavy texture.

The general distribution and concentration of salts and alkali in the Umatilla area are shown on the soil map by boundary lines and symbols in red. Three conditions or concentrations are indicated: (1) Alkali-free and salt-free areas where the accumulation of soluble salts or alkali is so small as not to injure crops. (2) A toxic condition where the salt or alkali is sufficient to injure the growth, production, or quality of most crops, or of all except those most tolerant of salts or alkali. This grade includes a rather wide variation of salt conditions. In some places the harmful effects are very slight, and in others crops grow only in spots or the yields are not greater than half those grown on salt-free and alkali-free areas. (3) Areas strongly affected by alkali or salts. These are mapped where the accumulations are such that the production of commercial crops is practically prevented and only saltgrass, greasewood, or other alkali- or salt-tolerant plants grow, or where the surface is practically barren, and is covered with alkali or salt crusts during dry weather.

In areas of the Stanfield soils, in Burke silt loan, saline phase, and to a limited extent in the other alkali- or salt-affected soils, accumulations of salts or alkali generally occur in the subsoil as well as in the surface soil. In most of the other soils, the salts have accumulated at the surface following evaporation of saline water.

A somewhat impervious condition in both the hardpan and the heavy-textured layers of the saline phase of Burke silt loam probably makes it impractical to attempt reclamation of that soil. The Stanfield soils could be reclaimed to such an extent that in many places at least shallow-rooted crops could be grown; the lime hardpan of these soils usually persists following the leaching of salts and alkalis, but it is generally porous and pervious to water. The permeability of practically all the other soil types is such that reclamation is not limited by it, but rather by conditions of poor underdrainage and seepage that have been intensified by irrigation. Reclamation of these lands, therefore, is dependent upon an adequate system of drainage—one that will keep the water table at least 4 feet and preferably 6 feet below the surface. Under such system, the land may be flooded and leached until the salts now concentrated principally at the surface are carried down through the soil and out with the underdrainage. In most of the strongly affected areas and in many places in the toxic areas, small quantities of black alkali, or sodium carbonate, are present. This alkali may be readily leached out of medium light or light-textured soils, but if the texture is heavy and if puddling occurs during leaching, the application of gypsum or sulfur will aid in the reclamation process.

If soils are reclaimed that are low in organic matter, this will probably have to be replenished by fertilization with manure or organic plant residues. Several bodies of volcanic ash are affected by alkali, and as the initial productive capacity of the land is low, it is very doubtful whether reclamation is practical; because of the porous character of the ash, however, very small quantities of water would be required to leach the salts. Organic matter could be supplied, following leaching, by applying manure, straw, or similar material.

In soils affected by salts and alkali, reclamation by use of drains and by leaching is thus far very limited. Two drainage ditches have been constructed and these have been effective in lowering the water table in the adjacent districts, thus preventing the further accumulation of salts and alkali, and they have made reclamation of some lands possible.

The concentration of salts and alkali in Stanfield very fine sandy loam is not high in the surface soil, yet rather large quantities occur between depths of 23 and 30 inches, which represents the hardpan layer of that soil.

An analysis of the salts from a sample of Burke silt loam, saline phase, shows that they consist mainly of sodium sulfate, with large quantities of sodium chloride but practically no sodium carbonate. It is probable that most of the alkali- or salt-affected areas of Sagemoor silt loam are somewhat similar in chemical constituents although in some places the content of carbonates is higher.

MORPHOLOGY AND GENESIS OF SOILS

Soil is the product of the forces of weathering and soil development acting on the soil materials deposited or accumulated by geologic agencies. Its characteristics at any given point depend on (1) the physical and mineralogical composition of the parent soil material; (2) the climate under which the soil material has accumulated and existed since accumulation; (3) the plant and animal life in and on the soil; (4) the relief or lay of the land; and (5) the length of time the forces of soil development have acted on the soil material. External climate is less important in its effects on soil development than internal soil climate, which depends not only on temperature, rainfall, and humidity, but on the physical characteristics of the soil or soil material and the relief. The relief, in turn, strongly influences drainage, aeration, runoff, erosion, and exposure to sun and wind.

The Umatilla area is of exceptional interest from the standpoint of the soil scientist. Here, within an east-west distance of 60 miles, is a range of climate, vegetation, and soils greater than that in some entire States, as great in fact, as that from the drier part of the Great Plains to the region of coniferous forests adjacent to the Great Lakes.

The area has a range in elevation from 250 feet above sea level on the Columbia River in the northwest to more than 4,000 feet in the Blue Mountains in the east, accompanied by a considerable range in temperature and a range in annual precipitation from less than 8 inches at Umatilla to more than 40 inches in the Blue Mountains. At Umatilla the average frost-free season is 199 days, whereas in the higher areas in the Blue Mountains frost may occur during any month of the year. The maximum and mean temperatures are highest in the lower part of the area around Umatilla, and the mean and minimum temperatures are much lower in the Blue Mountains.

Vegetation differs greatly in kind, vigor, and density in the lower and higher parts. The lower corner near the Columbia River is arid semidesert with native vegetation of shrubs and scattered bunchgrasses. In the plains and foothills the few areas that have not been broken by the plow have a native cover of bunchgrasses, which is denser and more vigorous in the higher elevations. The higher mountain areas are covered by a dense growth of Douglas-fir, white fir, spruce, and tamarack, with a few small open parklike areas; whereas the lower edge of the timbered belt has open stands of western yellow pine, with a considerable undergrowth of grasses and small shrubs.

From northwest to southeast representatives of the following zonal great soil groups may be found: (1) Sierozem, (2) Brown, (3) Chestnut, (4) Chernozem, and (5) Prairie, with Podzolic soils in the mountains. On the bottom lands and low terraces are a number of azonal and intrazonal soils.

The parent material from which the soils of a large part of the area have developed is loess, a remarkably uniform, fine floury, wind-borne material. Soils of considerable areas in the northwestern part of the county, however, have come from the sandy and gravelly deposits that make up the Columbia River terraces; some of those in the northern part have come from silty lake deposits; and in the higher plains, foothills, and mountains some of the soil materials have been produced by the decomposition and disintegration of the basaltic bedrock. The comparatively small areas of bottom lands, low terraces, and alluvial fans are largely from alluvial materials, but even these contain a considerable proportion of loess.

The origin of the loess is not certain. Probably it has come from a variety of sources and contains a considerable variety of minerals.

Possible sources are the deposits on the Columbia River terraces, the old lake terraces west and northwest of the area, and volcanic ash from former active volcanoes of the Cascades and intermountain region. Glacial flour and other fine materials from glacial outwash also may have contributed. As basalt is the dominant rock of this area it is probable that the loess contains many fine particles of basalt. On the other hand the drainage basin of the Columbia River is so large and contains such diverse kinds of rocks that it is obvious that the river deposits contain a wide variety of minerals. The sands and gravels of the terraces contain a large proportion of black fragments of basalt, but also much quartz and fragments of many other medium- and light-colored rocks and minerals.

The loess consists largely of silt-sized particles, with considerable very fine sand in places and comparatively little clay. The deposits of the Columbia River are dominantly sandy and gravelly, as are some of the older underlying deposits of the Umatilla and Walla Walla Rivers and their tributaries. Later stream deposits are largely of silty material. Old lake deposits are dominantly silty, although they contain some very fine sand and clay. The only soil materials that contain a high percentage of clay are the residual materials that have been formed by the decomposition of basaltic bedrock.

Although similar climatic and biologic influences acting on different soil materials tend to the formation of similar soils, seldom is the effect of the parent material fully overcome. Some of the soil differences in the Umatilla area appear to be due to differences in parent material, whereas others probably result from differences in climate and vegetation.

The widespread occurrence of loess and loesslike silty materials makes it possible to study the effects of climatic and biologic forces in many areas without having to make allowance for differences in parent materials. In other areas, however, the probability is that certain of the subsoil layers do not owe their clayey texture, blocky structure, and tough consistence to the weathering of loessal material or to the translocation of clay and colloids from above but come rather from the decomposition of the underlying basaltic bedrock.

In the central part of the area a great belt of semiarid upland plains is occupied by Walla Walla soils, which have developed from loess under a cover largely of bunchgrass. These soils appear to belong to the great group of Chestnut soils, although at the upper eastern edge of the belt they resemble Chernozem, and in the lower western part, Brown soils. Following is a profile description of Walla Walla silt loam near Athena, where the annual rainfall is about 18 inches:

0 to 8 inches, friable granular silt loam, brownish gray when dry and dusky brown or brownish black when moist. The content of organic matter is 2.18 percent, and the pH value 6.0.

8 to 15 inches, brownish-gray weakly prismatic silt loam. The prisms range from 2 to 4 inches on a side, are fairly distinct, but are very soft, crumble to small granules or powder, and may be removed intact only by very careful handling The content of organic matter is 1.68 percent, and the pH value 6.3.

15 to 24 inches, weak to pale-brown firm but friable silt loam containing 1.05 percent of organic matter and having a pH value of 6.6 In this layer the outline of the prisms is indistinct and the material lighter colored and of lower content of organic matter than that above.

24 to 60 inches, pale-brown soft friable noncalcareous silt loam, less granular than material of the upper layers, and easily crushed to a powder

60 to 98 inches, very pale-brown or very light brownish-gray highly calcareous friable light-textured silt loam, containing a few soft carbonate of lime nodules shaped like irregular spheroids and ranging from 1 to 3 mm. in diameter.

98 inches +, very pale-brown or light yellowish-brown moderately or highly calcareous soft floury silt loam, containing very little clay.

The outstanding characteristics of this soil are remarkable uniformity of texture throughout, soft floury consistence, and lack of definite structure. The accumulation of organic matter in the two upper layers and the concentration of lime below 60 inches are the only evidences of soil development, and these have failed to mask the character of the parent loess. The same general characteristics occur in the other Walla Walla soils and in the Ritzville soils, though the latter are definitely lighter in color and poorer in organic matter and have the layer of lime concentration closer to the surface.

The Athena soils are similar to the Walla Walla soils but are somewhat darker in color, slightly heavier in texture, more granular, and have lime at somewhat greater depth. They appear to belong to the great group of Chernozems and occur at somewhat higher elevations than the Walla Walla soils and under slightly greater rainfall. The prismatic structure of the subsoil is somewhat more distinct than in the Walla Walla series.

Walla Walla silt loam, light-textured phase, occurs at a slightly lower elevation and under slightly less rainfall than the typical soil and probably supported a somewhat less dense growth of grasses. It is very similar to the typical soil but the color is slightly lighter, the surface soil deeper, the structure slightly less granular, and the texture slightly lighter. This soil probably belongs to the Chestnut soils, but is not much darker than soils of the Brown group. It contains almost as much silt as the typical soil, but more very fine sand and less clay. A description of this soil, as observed about 3½ miles north of Pendleton at an elevation of about 1,500 feet above sea level, where the annual rainfall is about 14 inches, is as follows:

0 to 8 inches, brownish gray or pale-brown friable noncalcareous silt loam with very slight granulation but breaking generally from small clods to powder; dusky brown when moist.

8 to 16 inches, friable noncalcareous silt loam, slightly lighter in color than the surface soil. It is soft, may be easily crushed to a powder, and forms rather ill-defined soft prisms where exposed and allowed to dry in a cut bank.

16 to 46 inches, pale-brown or light yellowish-brown noncalcareous friable silt loam. It stands up well in a cut bank but is easily crushed to a flour and forms soft prisms 4 to 6 inches in diameter.

46 to 66 inches, mildy or moderately calcareous friable pale-brown or light yellowish-brown silt loam with a few soft nodules and some faint veins of carbonate of lime.

66 to 108 inches, pale-brown or very light yellowish-brown silt loam, slightly cemented by carbonate of lime but readily cut when dry by a moderate blow with a shovel. The very light color is owing in part to the lime carbonate.

108 to 144 inches, very light yellowish-brown floury silt loam, not cemented so much as the layer above and probably containing less carbonate of lime.

This soil has developed entirely from loess, and though slightly lighter in color, lower in organic matter, and less granular than most soils of the Chestnut group, it is very similar in other characteristics. Determinations were made of the content of organic matter of samples of this phase, taken from a cultivated field about 7 miles northeast of the location of the profile described above, where the elevation is 1,750 feet above sea level and the annual rainfall about 14.5 inches. The content of organic matter in the layer from 0 to 8 inches was 1.85 percent; 8 to 21 inches, 1.45 percent; and 21 to 44 inches, 0.96 percent.

Walla Walla very fine sandy loam is very much like Walla Walla silt loam but is lighter in texture, slightly lighter in color, and contains slightly less organic matter. In some characteristics it is transitional between the Walla Walla and the Ritzville soils.

In the belt of medium- to dark-colored soils of the high plains, associated in many places with the typical Walla Walla soils are a number that are developed from comparatively shallow mantles of soil material over basaltic bedrock or beds of cemented gravel. In these soils the upper layers are similar to those of the typical deep Walla Walla soils, but the lower material is influenced by the underlying substrata. The shallow phase of Walla Walla silt loam is generally less than 3 feet thick over bedrock or in places over cemented gravels. In many places its depth is 2 feet or less. Generally a layer several inches thick over the bedrock contains considerably more clay than the surface soil and the upper part of the subsoil and has a tougher consistence. In places a distinct concentration of carbonate of lime occurs in this layer. It appears that this clayey material comes not from the loess but from weathered bedrock.

The Pilot Rock soils are somewhat similar to shallow phases of the Walla Walla and Ritzville soils. They are shallow silty soils over lime-cemented gravel beds and have only a shallow layer of medium-dark surface soil over a light-colored limy subsoil. In many places a platy lime hardpan overlies the cemented gravel. Geologic erosion apparently has had a hand in keeping these soils thin, and the penetration of rain water has been shallow. The cemented gravel and hardpan retard downward movement of water, and much of the rain water that falls runs off rapidly. The Morrow soils are similar to the shallow phase of Walla Walla silt loam but have the heavy subsoil within a few inches of the surface. Probably most of the soil material has come from the decomposition of basaltic bedrock.

Extending westward in the plains from the districts where the Walla Walla soils occur are several soil types of the Ritzville series, which have developed where the annual rainfall is either slightly less than where the Walla Walla soils occur or is less effective owing to lower altitude and the accompanying warmer temperatures and greater evaporation. These soils appear to belong to the great Brown soil group, although they grade on the west and north into soils of the Sierozem group.

A profile of Ritzville silt loam examined about 3 miles northeast of Nolin at an elevation of about 1,200 feet above sea level, where the annual rainfall is about 12 inches, is described as follows:

0 to 9 inches, pale-brown very soft friable noncalcareous silt loam, containing little clay. The content of organic matter is 0.97 percent, and the pH value 6.6. (The content of organic matter in the 8-inch surface layer of a grass-covered virgin soil probably would be much higher.)

8 to 19 inches, similar to the layer above but slightly lighter in color and containing less organic matter. The pH value is 7.2.

19 to 33 inches, firm but friable light yellowish-brown noncalcareous silt loam, slightly lighter in color and apparently containing slightly less organic matter than the layer above. The pH value is 7.6.

33 to 46 inches, firm but friable very pale-brown or very light brownish-gray mildly calcareous silt loam; when moist, light brown with a pale yellowish tinge.

46 to 66 inches, slightly grayer than the layer above and slightly cemented by accumulated carbonate of lime, though easily dug with a shovel. Small chunks may be crumbled in the hand to a powder, which contains soft nodules of lime carbonate.

66 to 86 inches, soft silt loam, with less carbonate of lime, very light yellowish brown when dry and rich brown when moist.

Ritzville very fine sandy loam, fine sandy loam, and loamy fine sand are similar to Ritzville silt loam but differ mainly in texture of surface soil. The Quincy soils are somewhat similar to the Ritzville soils but are of lighter texture and come from materials that apparently are partly water-laid and partly wind-laid or wind-shifted. They appear to be intermediate between Brown and Sierozem soils.

In the extreme western part of the area at elevations ranging from 250 to 800 feet above sea level the average annual rainfall ranges from less than 8 to about 10 inches. Another such arid locality is along the southwestern edge of the Walla Walla Valley west of Umapine. In these areas the soils are somewhat similar to Desert soils, but the character of the native vegetation, including grasses as well as desert shrubs, the accumulation of organic matter in the surface soils, and the less calcareous nature of the surface soils indicate that they are Sierozem (gray soils) rather than true Desert soils. The Sagemoor soils, developed from fine silty lake-laid materials with some loess in places, are the most typical Sierozems and doubtless owe much of their grayness and high lime content to the character of the parent materials. The Ephrata, Rupert, and Winchester soils are too sandy and porous to develop well-defined zonal characteristics, although the Ephrata soils have a heavy concentration of lime in the subsoils.

A description of Sagemoor silt loam in the Walla Walla Valley is as follows:

0 to 13 inches, light brownish-gray or very pale-brown friable noncalcareous light-textured silt loam. The pH value is 7.9.

13 to 38 inches, very light brownish-gray or very pale-brown firm but friable moderately calcareous stratified materials ranging in texture from very fine sandy loam to silt loam. The pH value is 8.3.

38 to 48 inches, very light brownish-gray highly calcareous slightly cemented very fine sandy loam or silt loam. This material occurs in flattened lenses and appears to be weakly cemented by carbonate of lime, with possibly some silica.

48 to 72 inches +, very light brownish-gray or light-gray friable highly calcareous silt loam, with a few thin strata or lenses of somewhat firmer or weakly cemented material.

Because of the preponderance of finer textured material, high content of lime and salts, and strata of weakly cemented sediments, this soil has not been so favorable for penetration of moisture and roots, for plant growth, or for soil-developing forces in general as have associated soils from different parent materials under similar environmental conditions.

A description of a virgin profile of Ephrata loamy sand about 1½ miles southeast of Hermiston is as follows:

0 to 8 inches, friable or loose noncalcareous pale-brown or light brownish-gray loamy sand, containing 0.84 percent of organic matter and having a pH value of 7.3.

8 to 21 inches, light brownish-gray loamy sand. The content of organic matter is 0.83 percent, and the pH value 7.5.

21 to 35 inches, light brownish-gray sand, not so loamy as in the layer above. The content of organic matter is 0.52 percent, and the pH value 7.8.

35 to 50 inches, very light brownish-gray or very pale-brown friable sand, ranging from moderately to highly calcareous.

50 to 85 inches, very pale-brown moderately to highly calcareous loose sand and coarse sand, more porous than the layer above.

The greater part of this soil is underlain within 3 or 4 feet of the surface by porous beds of gravel, the upper part of which is slightly cemented by lime. This soil has been developed from old alluvial-terrace material, the surface of which has been more or less shifted by the wind. Vegetal cover consists of a sparse stand of downy bromegrass, rabbitbrush, sagebrush, bitterbrush, and a few inconspicuous grasses and weeds. The calcium carbonate has been accumulated below 35 inches, which is too deep to be representative of the Sierozem group. This depth is probably due to the deep penetration of rain water in an open and coarse-textured soil.

Soils of the Rupert series are somewhat similar to the Ephrata soils but have developed from coarser sandy materials and are so porous that comparatively little lime has concentrated in the subsoils.

In the higher part of the plain, and in the foothills and lower mountains is a belt of dark-colored granular soils that are generally not calcareous in any layer and appear to belong to the great group of Prairie soils. They are somewhat heavier than the Walla Walla and Athena soils, with definitely heavier subsoils, and are also shallower over bedrock. The group includes the Palouse, Waha, and Thatuna soils.

The Palouse soils apparently have developed largely from loess, although in places the heavy subsoil material may be residual from basalt. These soils typically are fairly deep—deeper than the Waha soils with which associated. A description of Palouse silt loam is as follows:

0 to 4 inches, dark brownish-gray heavy silt loam, brownish black or black when moist. Usually this is so densely matted with plant roots that structure is difficult to determine, but in places, the material has a thin platy structure. It is very friable and breaks into small granules. The content of organic matter is about 4 percent, and the pH value 6.6.

4 to 24 inches, friable and granular material of similar color and texture but not of platy structure. The content of organic matter is about 4 percent, and the pH value about 6.0.

24 to 31 inches, dark brownish-gray firm but friable prismatic heavy silt loam. The prisms are not of uniform size but vary from 1½ to 4 inches on the sides. They continue to a depth of about 44 inches, although their outline becomes less distinct and is almost lacking in the lower parts. The content of organic matter is 3 6 percent, and the pH value 6.1.

31 to 44 inches, weak-brown heavy silt loam with prismatic structure. The prisms are rather soft and friable and break readily into fine granules. This layer is much lower in organic matter than the one above.

44 to 55 inches, pale-brown or light yellowish-brown firm but friable silty clay loam. In a cut bank, the material appears massive, but it breaks readily into clods and with further pressure into granules.

55 to 80 inches, pale-brown or light yellowish-brown firm but friable heavy silt loam, with occasional angular or subangular rock fragments, especially in the lower part above the solid basaltic bedrock.

The soil described is fairly uniform in texture to a depth of 44 inches. To this depth it is heavy silt loam, with a clay content ranging from 26.7 to 28 percent. Between 44 and 55 inches the material is silty clay loam with 30 percent of clay. The next lower layer is somewhat lighter in texture and contains rock fragments. It seems probable that the material below 44 inches may be, in part, residual from basalt.

Associated with the Palouse soils, but usually lying on slopes with south, southwest, or west exposure, are bodies of the Waha series, which apparently have been subject to more rapid geologic erosion. They are dark-colored grass-covered soils, the surface layers of which appear to have developed, at least in part, from loess, and the subsoils probably from residual material from basaltic rock similar to that underlying the soil. Part of the heavy material of the subsoil may have been carried downward from the surface soil by the process of eluviation and illuviation, but it seems probable that most of it has been developed by hydrolysis and decomposition in place of the minerals composing the basaltic bedrock. Such decomposition produces a much heavier and more clayey parent material than loess. A few angular or subangular fragments of basaltic rock occur in the clayey layer that lies immediately over the solid bedrock. These fragments usually are most numerous near the basaltic bedrock. Soluble salts, including calcium carbonate, have been leached from the soil, and both surface soil and subsoil are slightly acid.

Thatuna silty clay loam occurs in the more extensive open parks in the belt of western yellow pine and immediately west of that belt where the elevation is slightly lower and the rainfall slightly less. The dominant native cover on areas that have not been plowed consists chiefly of bunchgrasses, but downy bromegrass, timothy, and other grasses are common, and much of the land is under cultivation. The profile is somewhat similar to that of Couse silt loam but it has a heavier texture, is more granular, darker colored, higher in organic matter, and the light-colored ashy subsoil layer is generally much thinner than in either Couse or Helmer silt loam. The soil has many of the characteristics of a degraded Chernozem. A profile description of Thatuna silty clay loam near Weston Mountain School is as follows:

0 to 2 inches, weak-brown friable granular silt loam or light silty clay loam, black when moist. Because of a matted network of roots this has formed a dense sod.

2 to 8 inches, similar to the layer above but with fewer grass roots. The content of organic matter from 0 to 8 inches in a newly cultivated field is 5.17 percent, and the pH value 5.7.

8 to 27 inches, weak to pale brown when dry and dark brown when moist. Somewhat granular friable silt loam or silty clay loam containing 2.33 percent of organic matter. The pH value is 5.7.

27 to 42 inches, pale- to very pale-brown slightly granular friable silt loam or silty clay loam, with 0.99 percent of organic matter and a pH value of 5.9.

42 to 49 inches, very pale-brown firm but friable silt loam that breaks into small clods and granules.

49 to 56 inches, light yellowish-brown slightly compact silty clay. Although slightly compact, this material has many tiny perforations about the size of a needle point through which moisture and air may circulate. Irregular-shaped cleavage planes are apparent and many are stained with dark colloidal material. Finely crushed material is a shade lighter in color.

56 inches+, light yellowish-brown slightly compact but friable silty clay loam or silty clay, with many tiny channels about the size of a pin point through which air and water may pass. This material breaks into irregular-shaped small clods when crushed in the hand.

The original material from which this soil has developed consisted mainly of loess, although basaltic bedrock underlies the soil and probably has contributed some of the soil material. The entire profile is neutral or slightly acid. Soluble salts have been leached away, and organic colloidal material appears to have been carried down into the subsoil, and probably some fine colloidal mineral material also. The heavy-textured clay subsoil, however, is probably a product of residual material developed from decomposition of basaltic bedrock.

At a depth of 42 to 49 inches the light-colored layer has been formed through gleization. During the period of excessive precipitation in spring, moisture appears to be perched temporarily in this layer immediately overlying the clay subsoil, and under anaerobic conditions in that zone the organic matter and iron become soluble. Some of it is deposited in seams or on cleavage planes in the lower layer, and probably some has been carried out of the soil while in solution, as water has moved down the hill slopes through the zone immediately over the top of the heavy-textured subsoil.

Associated with Thatuna silty clay loam and with Helmer silt loam are poorly drained mountain meadow areas that are mapped as Thatuna silty clay loam, poorly drained phase. The topography is such that drainage is sluggish. Vegetation consists of sedges, timothy, and related grasses and weeds that are adapted to wet slightly acid soils.

The light-colored Podzolic soils of timbered areas in the Blue Mountains are represented by Helmer silt loam. Where this soil has developed, the elevation ranges from about 3,000 to 4,000 feet above sea level and the annual precipitation from about 32 to 42 inches, much of it falling as snow. Summer temperatures are seldom higher than 85° F., and below-freezing temperatures are common most of the winter. The mean annual temperature is about 38°. Description of a typical profile of Helmer silt loam under native timber cover, which consists of rather dense stands of fir, spruce, and tamarack, is as follows:

0 to ½ inch, weak-brown or dark-brown undecomposed twigs and needles.

½ to 1 inch, weak to dark-brown decomposing needles.

1 to 1⅛ inches, very pale-brown or light brownish-gray ashy friable very fine sandy loam. This appears to be very siliceous mineral material, which possibly is of podzolic character and has been leached of iron. The high pH value (7.0) may indicate that the material is ash produced by the burning of a former surface organic layer.

1⅛ to 8 inches, light yellowish-brown fluffy or floury silt loam, moderate brown when moist. The content of organic matter is 1.74 percent, and the pH value 6.0.

8 to 18 inches, very similar to the layer above but slightly lighter in color and lower in organic matter. The content of organic matter is 1.26, and the pH value 5.7.

18 to 28 inches, yellowish-white to white floury or ashy silt loam. The thickness of this ashy layer is variable—in some places it appears only as grayish-white mottling but in others it is 20 inches or more thick. This is a second layer of the profile that has been leached.

28 to 36 inches, very pale-brown firm but friable heavy silt loam, somewhat mottled with gray. This appears to be a transitional layer in which some fine-textured material has been accumulated and from which some materials have been leached to give rise to the grayish cast. The mottled condition indicates fluctuations of the water table.

36 inches+, light yellowish-brown heavy silty clay loam or silty clay, highly mottled with gray and rusty-brown iron stains and containing many small iron concretions. Though the clay is somewhat compact, it contains many tiny holes the size of a needle point and is slowly pervious. In many places this material continues to basaltic bedrock, which in many places lies within 6 feet of the surface though in others it is 15 feet or more. Below a depth of 4 to 6 feet and continuing to bedrock are usually a few small somewhat angular basaltic fragments.

This soil resembles the Brown Podzolic soils in several features. The gray ashy layer is very thin, and deposition of iron is not markedly apparent immediately below the thin gray layer. The lower gray or nearly white layer, which probably represents a ground-water podzolized or glei horizon, is not typical of the true Brown Podzolic soils.

Couse silt loam, which is generally a little lower in elevation than the Helmer soils, occupies districts where there is or has been a moderate or dense stand of pine, and where either less rain falls than in areas of Helmer soils, or because of a shallower soil there is less moisture available for use by plants. An undergrowth of grass and shrubs is more common than on the Helmer soils.

The surface soil of Couse silt loam is slightly less acid than that of the Helmer soils and is considerably darker and higher in content of organic matter. To an average depth of 5 inches it is weak- to pale-brown friable slightly granular silt loam. Between 5 and 12 inches is weak- to pale-brown friable silt loam that breaks into irregular-shaped clods and crumbs when dry. Beneath this and to a depth of about 22 inches the soil material is similar but slightly paler because of less organic residue and slight gleization. Below this layer is the characteristic very pale-brown or nearly white ashy layer that apparently is a product of gleization. Immediately below the ashy layer, or at an average depth of 27 inches, is a rather compact heavy clay loam or clay of pale-brown color highly mottled with rusty-brown iron stains. The origin of the clay material, which continues to basaltic bedrock, appears to be the residual weathered material from the underlying rock.

The soil-forming processes and the explanation of development of Couse silt loam are similar to those of Helmer silt loam, but, because of differences in environmental conditions pine trees instead of fir, spruce, and tamarack have established themselves. These trees are less dense than those growing on the Helmer soils; they allow considerable growth of shrubs and grass, and shade the ground less. As a result the soil dries out more during the dry summer season. It contains more organic matter than the Helmer soils because of the more abundant grasses.

In the lower parts of the Umatilla area the annual rainfall is low and the rate of evaporation high. There are, however, a number of poorly drained intrazonal soils of the Caldwell, Stanfield, Burke, and Umapine series that are affected more or less by an accumulation of salts. In some places, as is generally the case with the Umapine soil and with the saline phases of the Caldwell soils, the salts are present in free form and are rapidly dissolved and carried down into the soil a few inches when rain falls, but return to the surface as rapidly when evaporation occurs. The white salt crust is generally very soft. It may remain on the surface for days, may be carried away by wind, or may be returned to the subsurface or subsoil by subsequent rain water.

In the Stanfield soils and in Burke silt loam, saline phase, at depths of 12 inches to 6 feet below the surface is a cemented layer, or hardpan, which ranges in thickness from less than 1 inch to 10 or 12 inches and in consistence from rather soft mealy material to very hard formations that are difficult to penetrate with a soil auger but may be broken with a pointed iron bar. This cemented layer is sufficiently porous to allow considerable circulation of air and a slight or moderate degree of percolation of water. Roots of grasses do not penetrate the pan, though in some places greasewood roots have grown through it.

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This hardpan is highly calcareous, and apparently the cementing material is largely calcium carbonate, deposited at or near the surface of a high water table. The layer also contains a high percentage of sodium salts, especially the sulfate and carbonate, and possibly a part of the density of the material may be due to deflocculation of the soil colloids by sodium. In spots, a brown claypan overlies the lime hardpan. The material is dense and has a prismatic or blocky structure. Probably the soil in these spots is a Solonetz or alkali-claypan soil.

Detailed descriptions of the soils affected by salts are given in the section on Soils. The salty or saline soils represent the Solonchak group of intrazonal soils, and the process of development is salinization. The soils with claypans may be related to the Solonetz intrazonal group where the process is solonization. The pans that consist essentially of calcium carbonate are the result of geologic processes and to some extent of calcification, whereby opportunity was given for the infiltration of relatively large quantities of calcium.

The most nearly typical Solonetz in this area is McKay silt loam, a profile description of which is as follows:

0 to 10 inches, brownish-gray to pale-brown friable and granular heavy silt loam, containing 2.78 percent of organic matter and having a pH value of 6.0. When moist, the soil is dark brown to dusky brown.

10 to 13 inches, brownish-gray to pale-brown platy and friable heavy silt loam having 2.73 percent of organic matter and a pH value of 6.8.

13 to 19 inches, brownish-gray to pale-brown friable heavy silt loam. It is grayer than the preceding layer, contains 1.85 percent of organic matter, and has a pH value of 7.2.

19 to 27 inches, slightly compact and very distinctly columnar silty clay loam, the cleavage surfaces of which are coated with humus This material is dark brown to weak brown, but when finely crushed becomes brownish gray. The rounded or biscuitlike tops of the columns are usually coated with a thin film of gray ashy silty material The content of organic matter is 1.32, and the pH value 7.2. No effervescence occurs when dilute hydrochloric acid is applied. Although this columnar material appears to be very dense, it contains many tiny channels or pores that permit circulation of air and percolation of water.

27 to 35 inches, pale-brown mildly calcareous silt loam that has a tendency to become massive, and, although firm, it is easily broken into small clods and crumbs or to a powdery form Like the material of the preceding layer, this horizon contains many tiny channels or pores the size of a needle point Gray veins of calcium carbonate occur.

35 to 46 inches, pale- to very pale-brown material with many gray veins and mottlings where calcium carbonate has accumulated. This is firm but friable highly calcareous heavy silt loam.

46 to 60 inches, well water-worn or slightly angular gravelly materials firmly cemented by gray or white carbonate of lime. Most of the gravel is of basaltic origin.

60 inches +, very similar to the layer above but not so high in content of calcium carbonate The gravelly material is more than 10 feet thick in some places, though in others basaltic bedrock occurs at depths of 6 to 10 feet.

This soil has many of the characteristics of degraded Solenetz, and possibly solonization has been responsible for the formation of the columnar structure. Subsequent to the formation of the Solonetz and perhaps after a period of better drainage and the degradation of the soil, other material may have been deposited on top of the columnar clay material. It is evident that conditions have varied from place to place or that the intensity of soil processes has differed from place to place, because in some comparatively flat areas a gray ashy layer 2 to 4 inches thick overlies the columnar material.

As outlined previously, the solonization process includes the action of an excess of exchangeable sodium ions that cause the deflocculation of clay and its accumulation in columnar form, after which, because of better drainage, the excess of alkali is largely removed by leaching. Because of more suitable conditions for growth, the surface soil becomes grass-covered to such an extent that appreciable accumulations of organic matter are incorporated with the soil material.

A number of other important agricultural soils are azonal, including several that have developed in flood plains of rivers, creeks, and intermittent drainage channels and that differ considerably in character, age, accumulation of organic matter, and drainage. These soils are discussed in the section on Soils. They include the Snow, Caldwell, Hermiston, Onyx, and Yakima soils.

The results of pH determinations of a number of soil profiles are given in table 9.

The mechanical analyses of several soils are given in table 10.

TABLE 9.—*pH determinations of several soil profiles from the Umatilla area, Oreg.* [1]

Soil type and sample No.	Depth	pH	Soil type and sample No	Depth	pH
Helmer silt loam:	*Inches*		Walla Walla silt loam	*Inches*	
562101	0– ¾	5.4	562184	0– 8	6.0
562102	¾– 1¼	5.8	562185	8– 15	6.3
562103	1¼– 1 5/16	7.0	562186	15– 24	6.6
562104	1 5/16– 8	5.8	562187	24– 36	6.9
562105	8– 18	5.7	562188	36– 60	7.1
562106	18– 28	5.5	562189	60– 68	7.7
562107	28– 46	5.2	562190	68– 96	8.0
562108	46– 72	5.1	Couse silt loam		
Thatuna silty clay loam:			5621113	0– 6	6.0
562109	0– 8	5.8	5621114	6– 12	5.6
562110	8– 27	5.8	5621115	12– 21	5.8
562111	27– 42	5.6	5621116	21– 34	5.8
562112	42– 49	5.7	5621117	34– 37	5.8
562113	49– 56	5.4	Waha silty clay loam		
Couse silt loam			5621118	0– 5	6.4
562114	0– ½	5.6	5621119	5– 10	6.4
562115	½– 5	6.4	5621120	10– 18	6.7
562116	5– 12	5.7	5621121	18– 21	6.7
562117	12– 22	5.5	Hermiston silt loam		
562118	22– 27	5.2	5621137	0– 8	7.3
562119	27– 36	5.0	5621138	8– 16	7.6
Ritzville silt loam			5621139	16– 32	8.1
562135	0– 8	6.7	5621140	32– 56	7.9
562136	8– 19	6.7	Stanfield very fine sandy loam		
562137	19– 33	7.4	5621141	0– 9	8.4
562138	33– 46	8.9	5621142	9– 23	9.7
562139	46– 66	9.4	5621143	23– 30	9.7
562140	66– 86	9.1	5621144	30– 46	9.2
Palouse silt loam			5621145	46– 72	7.9
562156	0– 4	6.4	Walla Walla silt loam, light-		
562157	4– 21	6.3	textured phase		
562158	21– 24	5.8	5621203	0– 8	6.5
562159	24– 31	6.1	5621204	8– 16	6.8
562160	31– 44	6.8	5621205	16– 46	7.6
562161	44– 55	6.5	5621206	46– 66	8.3
562162	55– 80	6.8	5621207	66–108	8.7
McKay silt loam			5621208	108–144	8.9
562163	0– 10	5.7	Volcanic ash:		
562164	10– 13	6.2	5621211	0– 7	7.7
562165	13– 19	7.0	5621212	7– 21	7.9
562166	19– 27	7.0	5621213	21– 36	9.4
562167	27– 35	8.5	5621214	36– 56	9.0
562168	35– 46	8.5	5621215	56– 66	9.1
562169	46– 56	8.5	5621216	66– 78	9.1

[1] Determinations made by the hydrogen-electrode method by E. H Bailey, assistant soil technologist, laboratories of the Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture.

TABLE 10.—*Mechanical analyses of samples of several soils from the Umatilla area, Oreg.*

Soil type and sample No.	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
	Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Helmer silt loam								
562103	1¼ - 1 5/16	1.1	0.6	0.8	7.1	11.2	63.2	16.0
562104	1 5/16 - 8	.3	.6	1.0	9.2	12.6	69.3	7.1
562105	8 - 18	.2	.5	1.0	8.7	12.6	72.2	4.8
562106	18 - 28	.1	.2	.5	9.5	19.4	66.2	4.0
562107	28 - 46	.3	.5	.5	1.2	10.0	67.3	20.1
562108	46 - 72	1.3	1.6	.9	1.9	6.3	59.4	28.7
Couse silt loam								
562114	0 - ½	2.5	3.3	1.8	5.0	7.7	62.9	16.9
562115	½ - 5	.6	.7	.5	3.7	7.8	60.0	26.7
562116	5 - 12	.2	.4	.4	4.0	9.0	59.4	26.6
562117	12 - 22	.1	.5	.5	2.6	9.3	64.1	22.8
562118	22 - 27	.9	1.1	.7	1.7	10.0	74.6	11.0
562119	27 - 36	1.0	.8	.4	1.0	3.8	40.4	52.6
Ritzville silt loam								
562135	0 - 8	.1	.2	.5	3.2	18.1	63.0	15.0
562136	8 - 19	.1	.2	.5	3.6	17.1	64.6	14.0
562137	19 - 33	.1	.1	.4	2.8	19.3	66.5	10.7
562138	33 - 46	.1	.2	.3	1.9	11.3	73.1	13.2
562139	46 - 66	.4	2.1	1.5	5.3	17.3	64.7	8.7
562140	66 - 86	.1	.9	1.5	9.1	20.1	59.8	8.4
Ritzville very fine sandy loam								
562141	0 - 8	.6	.7	.9	6.1	27.2	57.2	7.3
562142	8 - 23	.2	.8	1.1	9.0	33.6	49.2	6.1
562143	23 - 35	.6	.9	.7	5.2	24.2	63.9	4.5
562144	35 - 48	1.3	1.0	.5	2.8	19.9	69.4	5.1
562145	48 - 54	2.3	2.9	1.1	3.2	21.2	61.1	8.2
562146	54 - 86	.5	1.2	.7	2.0	18.8	70.2	6.6
562146A	86 -108	.5	.7	.3	1.3	15.5	75.7	6.0
Palouse silt loam								
562156	0 - 4	.5	.8	.3	3.0	8.9	59.8	26.7
562157	4 - 21	.2	.4	.3	2.5	9.0	59.6	28.0
562158	21 - 24	.2	.3	.2	2.1	8.4	62.1	26.7
562159	24 - 31	.2	.3	.2	2.2	8.5	60.6	27.9
562160	31 - 44	.2	.3	.2	2.4	8.9	60.7	27.4
562161	44 - 55	.2	.4	.2	1.4	10.0	57.7	30.0
562162	55 - 80	.2	.3	.2	.7	8.7	64.4	25.5
McKay silt loam								
562163	0 - 10	.5	.5	.4	4.1	9.3	63.6	21.6
562164	10 - 13	.4	.5	.4	4.1	8.9	62.8	22.9
562165	13 - 19	.7	.6	.4	3.4	8.7	64.1	22.2
562166	19 - 27	.3	.6	.3	1.4	5.8	55.0	36.7
562167	27 - 35	.7	.6	.3	1.9	9.3	69.6	17.6
562168	35 - 46	1.7	1.6	.8	3.5	8.6	59.4	24.4
562169	46 - 50	9.2	6.3	3.0	5.7	6.6	29.5	39.8
Sagemoor silt loam								
562170	0 - 13	.1	.5	1.5	11.5	25.7	51.0	9.7
562171	13 - 38	.1	.3	.4	2.4	12.7	72.9	11.2
562172	38 - 47	.1	.3	.5	2.1	7.8	81.8	7.4
562173	47 - 60	.1	.2	.2	1.8	12.2	70.8	5.7
Walla Walla silt loam								
562184	0 - 8	.1	.2	.4	3.2	11.2	62.4	22.6
562185	8 - 15	0	.4	.7	3.4	12.2	60.4	22.9
562186	15 - 24	0	.1	.2	2.2	14.2	63.5	19.8
562187	24 - 36	0	.2	.2	1.4	15.7	63.8	18.8
562188	36 - 60	0	.2	.1	1.0	12.7	66.8	19.3
562189	60 - 68	0	.4	.3	2.7	13.8	69.6	13.3
562190	68 - 96	.1	1.3	2.1	6.5	17.5	62.4	10.0
Caldwell silt loam, saline phase								
5621104	0 - 18	0	.3	.8	6.0	14.5	67.5	10.9
5621105	18 - 24	0	.2	.4	4.5	10.2	69.2	15.5
5621106	24 - 60	0	.3	1.3	8.3	10.2	66.6	13.3
5621107	60 - 72	0	1.0	6.0	30.9	17.3	35.2	9.6
Couse silt loam								
5621113	0 - 6	.4	.6	.4	3.0	6.8	59.1	29.7
5621114	6 - 12	.9	.6	.3	2.7	6.1	58.0	31.4
5621115	12 - 21	1.2	1.1	.6	1.7	6.8	59.0	29.6
5621116	21 - 34	.5	.5	.3	2.4	6.5	60.2	29.6
5621117	34 - 37	.2	.5	.8	4.5	7.9	25.3	60.7
Waha silty clay loam								
5621118	0 - 5	1.8	1.1	.5	3.5	7.7	54.8	30.6
5621119	5 - 10	1.5	1.2	.5	3.5	7.9	53.7	31.7
5621120	10 - 18	1.1	1.0	.4	1.2	7.3	49.2	39.8
5621121	18 - 21	3.5	3.2	1.2	2.7	6.5	41.8	41.1
Hermiston silt loam								
5621137	0 - 8	.3	.3	.4	3.8	15.1	61.7	18.4
5621138	8 - 16	.1	.2	.4	4.1	15.1	62.2	17.9
5621139	16 - 32	.2	.5	.7	4.9	17.0	60.1	16.5
5621140	32 - 56	.4	1.4	1.3	4.0	16.1	61.2	15.5

TABLE 10.—*Mechanical analyses of samples of several soils from the Umatilla area Oreg.*—Continued

Soil type and sample No.	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
Stanfield very fine sandy loam	*Inches*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
5621141	0 - 9	0.3	0 8	1 3	8 8	35 9	44 8	8 0
5621142	9 - 23	0	6	1 2	9 2	38 8	44.4	5.7
5621143	23 - 30	5 3	9 7	3 6	7 1	23 9	43 6	6 9
5621144	30 - 46	2	2 7	2 6	5.5	19 4	58 7	11 0
5621145	46 - 72	0	2	6	4 9	10 2	71.8	12 3
Walla Walla silt loam, light-textured phase								
5621203	0 - 8	0	2	.4	4 5	15 7	61 1	18 2
5621204	8 - 16	0	2	.5	4 6	16 3	60 0	18.5
5621205	16 - 46	0	0	.3	2.2	16 3	71 1	10 1
5621206	46 - 66	1	.2	.4	3.4	17.6	70.3	8 0
5621207	66 -108	.1	1 8	1.8	5.2	15.0	70 5	5 5
5621208	108 -144	.1	9	1.5	4.5	20 3	65 5	7 2
Volcanic ash								
5621211	0 - 7	.1	6	1 7	13.6	36 4	43 3	4.3
5621212	7 - 21	.1	6	2 6	14 4	27 2	52 6	2 5
5621213	21 - 36	.1	7	1 8	5 8	17 3	71 5	2.7
5621214	36 - 56	0	5	1 9	9 3	13 6	66 1	8 6
5621215	56 - 66	2 1	2 7	2 2	6 1	12 6	62 4	12 0
5621216	66 - 78	1 3	2 8	2 4	5.3	11.6	64.7	11.9

GENERAL KEY TO THE SOILS OF THE UMATILLA AREA, OREG.

I. MEDIUM TO DARK-COLORED SOILS OF THE SMOOTH TO ROLLING UPLAND LOESSAL PLAINS; LIME IN LOWER SUBSOIL.
- A. Deep soils from loess.
  - 1. Dark brownish-gray to brownish-black soils.
    - Athena silt loam.
  - 2. Brownish-gray to dark brownish-gray soils.
    - Walla Walla silt loam.
  - 3. Brownish-gray to light brownish-gray soils.
    - Walla Walla silt loam, light-textured phase.
    - Walla Walla very fine sandy loam.
- B Shallow soils from loess and silty alluvium.
  - 1. Brownish-gray to dark brownish-gray soils.
    - Walla Walla silt loam, shallow phase.
    - Pilot Rock silt loam, deep phase.
    - Morrow silty clay loam.
  - 2. Brownish-gray to light brownish-gray soils.
    - Pilot Rock silt loam.
    - Morrow silt loam.
  - 3. Dark brownish-gray medium-shallow claypan soils (Solonetz).
    - McKay silt loam.

II. LIGHT-COLORED SOILS OF THE SMOOTH TO ROLLING UPLAND PLAINS AND LAKE TERRACES.
- A Deep soils.
  - 1. Pale-brown soils from loess.
    - Ritzville silt loam.
    - Ritzville very fine sandy loam.
    - Ritzville fine sandy loam.
    - Ritzville loamy fine sand.
  - 2. Pale-brown or light brownish-gray soils from silty lake deposits.
    - Sagemoor silt loam.
- B. Shallow soils.
  - 1. Pale-brown soils from loess.
    - Ritzville silt loam, shallow phase.
    - Ritzville very fine sandy loam, shallow phase.
  - 2. Pale-brown or very light brownish-gray soils from silty lake deposits.
    - Burke silt loam, saline phase.

III. DARK-COLORED SOILS OF THE FOOTHILLS AND LOWER MOUNTAINS.
- A. Dark brownish-gray to brownish-black deep soils.
  - Palouse silt loam.
  - Palouse silt loam, steep phase.
  - Waha silt loam, deep phase.
  - Waha silty clay loam, deep phase.
- B. Dark brownish-gray to brownish-black shallow soils.
  - Waha silt loam.
  - Waha silty clay loam.
- C. Dark-brown deep soils.
  - Thatuna silty clay loam.
  - Thatuna silty clay loam, poorly drained phase.

IV. LIGHT-COLORED SOILS OF THE BLUE MOUNTAINS.
- A. Pale-brown soils.
  - Couse silt loam.
- B. Light yellowish-brown soils.
  - Helmer silt loam.

V. LIGHT-COLORED SANDY SOILS OF THE COLUMBIA RIVER TERRACES
- A. Sandy soils over finer textured limy subsoils.
  - Quincy loamy fine sand.
  - Quincy loamy fine sand, wind-eroded phase.
  - Quincy loamy fine sand, shallow phase.
  - Quincy fine sand.
  - Quincy fine sand, hummocky phase.
- B. Sandy soils over lime-cemented gravel.
  - Ephrata loamy sand.
  - Ephrata loamy sand, poorly drained phase.
  - Ephrata sand.
  - Ephrata sand, shallow phase.
  - Ephrata fine sandy loam.
- C. Excessively loose porous sandy soils (little or no lime in subsoil).
  - Rupert coarse sand.
  - Rupert sand.
  - Winchester sand.

VI. SOILS OF THE BOTTOM LANDS AND LOW TERRACES.
- A. Dark-colored deep well-drained soils.
  - Snow silt loam.
  - Caldwell silt loam.
- B. Dark-colored deep imperfectly drained soils.
  - Caldwell silt loam, saline phase.
  - Caldwell silty clay loam, saline phase.
- C. Brown or pale-brown deep friable soils.
  - Onyx loam.
  - Onyx fine sandy loam.
  - Onyx loamy fine sand.
- D. Medium to light brownish-gray soils over limy subsoils.
  - Hermiston silt loam.
  - Hermiston very fine sandy loam.
- E. Brown or pale-brown shallow soils over gravel beds.
  - Yakima cobbly loam.
  - Yakima gravelly loam.
  - Yakima loam.
  - Yakima silt loam.
- F. Very light brownish-gray soils over limy subsoil or hardpan.
  - Stanfield very fine sandy loam.
  - Stanfield fine sand.
  - Umapine very fine sandy loam.

VII. MISCELLANEOUS NONARABLE SOILS AND LAND TYPES.
- A. Shallow stony soils.
  - Waha stony silt loam.
  - Underwood stony loam.
  - Shallow stony soils.
  - Scabland.
- B. Steep stony soils.
  - Rough broken and stony land.
  - Rough broken and stony land, timbered phase.
- C. Loose gravelly and sandy materials.
  - Riverwash.
  - Volcanic ash.

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