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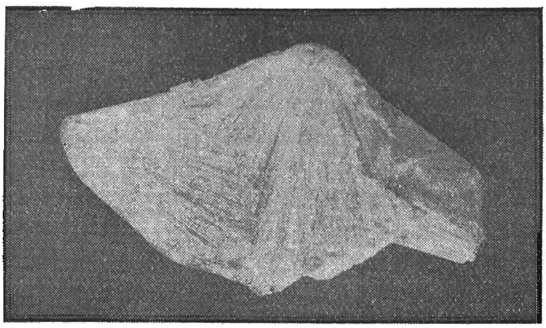
OREGON AGRICULTURAL EXPERIMENT STATION.

CHEMICAL DEPARTMENT.

THE FERTILITY OF OREGON SOILS.



"The next thing is to tickle the soil with tillage; and see if it will laugh with fatness; if it does not, apply something which will awaken it more effectually."—*Roberts in The Fertility of the Soil.*

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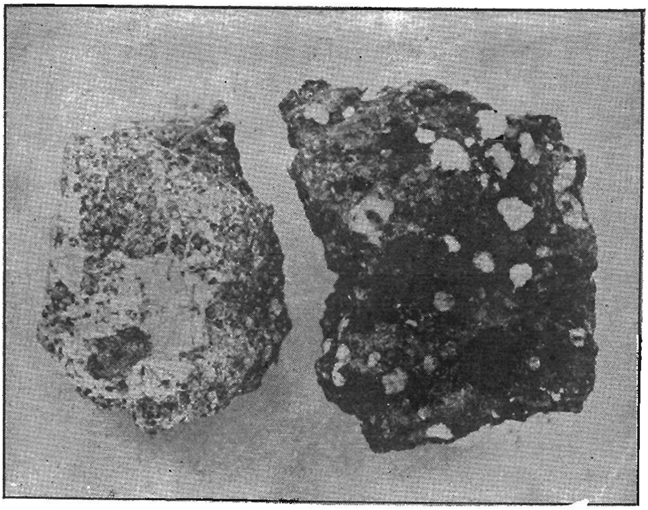
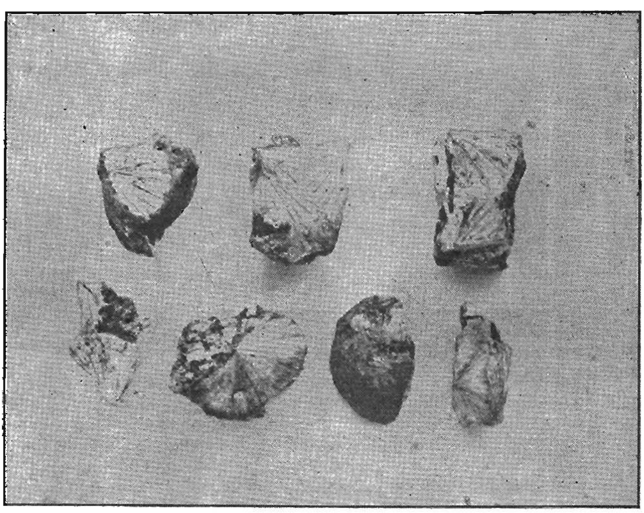


LIME-BEARING ZEOLITES IN RCCKS.



LIME-BEARING ZEOLITES.

INTRODUCTION.

In October, 1892, the writer published in Bulletin 21 the results of the examination of a number of soils of this State. Since the publication of those preliminary results, the work on soils has progressed more or less rapidly as other lines of investigation, more urgent in their need, would permit. The results obtained within this period have revealed some facts of importance, and have, in some measure, modified certain ideas held at the time of publishing the former bulletin. Particularly is this true of the lime supply of Oregon soils which will be discussed more at length in this publication.

The edition of the former bulletin was exhausted soon after publication, hence in addition to a discussion of the analyses proper it has been thought best to set before the reader some fundamental facts concerning the properties of soils and the function of their critical elements. It is the experience of the writer that there is much need of the elementary instruction which the first part of this bulletin essays to cover, and it is hoped that it may serve a goodly purpose in stimulating interest in agricultural problems.

G. W. SHAW,
Chemist.

THE FERTILITY OF OREGON SOILS.

G. W. SHAW, PH. D.

At the outset I desire to state that often much more importance is attached to a chemical analysis of soil than is warranted. Chemists would be more than glad to claim for this work all that many people imagine it is possible to tell from such analysis, but we are compelled to admit that the analysis of a single soil tells but little in a positive way. Chemists have long been divided in opinion as to whether the benefits to be derived are commensurate with the labor expended, for a soil analysis is a tedious undertaking requiring several days for its completion. The main ideas advanced by the opposition are:

First. The inability of securing a sample which will represent a general average.

Second. The difficulty in establishing a rule for determining deficiencies of plant food, because of the very material differences in the physical properties of soils.

Third. The inability of the chemist to determine the *availability* of the plant food in a soil.

The opinions of those holding these views were the natural outgrowth of those holding incorrect views put forth in the beginning of agricultural chemistry, and of the fact that the earlier work with soils was done upon the "worn-out soils" of Europe and the Eastern States.

On the other hand there are equally strong adherents to the belief that much of value results from a careful chemical examination of soils, and in rebuttal to the objections stated above they offer:

First. That the objection does not hold except when a very limited number of samples is considered in the average. That when a large number of analyses are made of soils of essentially the same characteristics a very staisfactory idea can be had as to any inherent deficiency in the soils of like character, and the larger the number of analyses on which the averages are based the more definite becomes our knowledge, *provided uniform methods of sampling and analysis are employed.*

Second. That on the prairies and hills of the great west *vast tracts of land*—often larger than an entire state in the east—*of essentially the same physical characteristics*, still in their virgin state, concerning which it is possible to establish certain minimum limits for productiveness as indicated by marked differences in the characteristics of the plants growing thereon.

Third. That while it is admitted as impossible at present for the chemist to answer definitely concerning the availability of plant food; he can answer as to the total quantity, and any inherent deficiency found will certainly limit the durability; that it is possible to say with a fair degree of assurance on which side the soil will first wear out. Further, it can now fairly be claimed that recent investigations furnish reasonable ground to expect that in the not far distant future even the availability of plant food in the soil may be ascertained.

Fourth. "That it is far easier to start with only a few known facts, even without a knowledge of how best to use them, in the endeavor to determine the best practice, than to ignore these fundamental facts."*

ORIGIN OF SOILS.

Soils are formed by the natural disintegration and abrasion of the original rock masses. This disintegration and the subsequent pulverization is known as "weathering." The action of the natural agents causing this change of rock to soil is partly mechanical and partly chemical. The agents entering into the process are change of temperature, water, air, and organic life. Considering these in turn: changes from heat to cold subject the rock to alternate expansion and contraction, which, on account of the heterogeneous nature of the rock mass, finally results in producing small cracks and fissures into which rain may fall and moisture collect, which upon freezing exerts its tremendous expansive force—one-fifteenth of its mass—sufficient to rend large rock masses in twain and cause them to crumble to smaller portions, the effect being in proportion to the amount of moisture that has collected in the fissures and pores of the rock and to the severity of the frost. Of course the more rapid changes take place near the surface, but the action is extended even to the hard rock, which becoming exposed to frequent alterations of dryness and moisture, heat and cold, soon crumbles to fragments.

* The Fertility of Soil, page 140, Roberts.

Water is the great transforming force in nature,* and acts both as a mechanical and a chemical agent. It is a soil former whether it be in the running stream, in the quiet lake or in the falling rain. Running water is chief among the abrasive forces, for with every particle removed increased erosive power is acquired, and every grain of sand coöperates with its neighbor in grinding away the solid masses against which it is driven, and these themselves by their mutual rubbing grind each other till the angular fragments become pebbles and the pebbles sand or mud. The chemical effect of water is no less than its mechanical for not only does the water as such exert its action, but associated with it are dissolved gases, principally carbon dioxid and oxygen, which themselves are active forces in forming new compounds, thus weakening cohesion and adding to the general destruction of rocks and their reduction to soils.

The action of the atmosphere is also due to carbon dioxid and oxygen, the latter acting as an oxidizing agent in converting the lower into the higher oxids. Iron and manganese, which enter into the composition of a great variety of rocks are thus affected. Thus the air is a potent agent in the formation of soils.

Plants have aided much in soil formation both by the disintegrating action of their rootlets, which have much the same effect on rocks as freezing water, and by the accumulation of their decaying remains and their incorporation with the mineral matter.

On the animal side earthworms are an important factor in this process not only by bringing to the surface portions of the subsoil to be subjected to the action of atmospheric agents, but also in influencing its physical state by making it more porous and friable. "It is probable that the whole of vegetable matter in soil passes sooner or later through the alimentary canal of these ceasless soil builders, and is converted into the form of humus." †

Were the decomposing agents the only ones that are active all soils would be formed *in situ* and would represent the remains of the parent rock enriched by the decomposing vegetable matter, but a large portion of our soils are the result of water deposition, either fresh or salt, of finely eroded particles prepared elsewhere than in their present location. In all running water fine material is carried to a lower level and streams are continually moving

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* Rocks and Soils, Stockbridge.
† Principles of Agriculture Analysis, Wiley, Vol. I. page 50.

soils from one point to another. It is thus that the fertile alluvial, or "bottom lands," are formed. Ordinarily, however, the rocks of a given locality have formed, or contributed very much, to the soils of that section.

DEFINITION AND FUNCTION.

"The term soil, in its broadest sense, is used to designate that portion of the earth which has resulted from the disintegration of rocks and the decay of plants and animals, and which is suited under proper conditions of moisture and temperature, to the growth of plants. It consists, therefore, chiefly of mineral substances, together with some products of organic life, and certain living organisms whose activity may influence vegetable growth either favorably or otherwise. The soil also holds varying quantities of gaseous matter and of water, which are important factors in its functions,"* which are

First, to act as a mechanical support for plants.

Second, to furnish ash ingredients to the plant.

Third, to act as a storehouse of moisture for the use of plants.

Fourth, to aid in developing the plant by modifying and storing the sun's heat, regulating the food supply and securing other important conditions.

The term *subsoil* is used to designate that portion lying directly beneath the soil. In arid regions the line of demarcation, which is generally quite marked, the subsoil being of lighter color than the soil proper, largely disappears making it impossible to distinguish any difference either in color or texture to a depth of many feet. This is well illustrated in many soils in Eastern Oregon where no line of demarcation appears for a depth of 20 feet or more, while in the Willamette valley the clay subsoil is well marked.

A BIT OF CHEMISTRY.†

In a discussion of such a subject as the one in hand it is well nigh impossible to avoid altogether the use of certain chemical terms. From this reason and from the further fact that a great many readers of this bulletin will not have had any chemical training, the following fragment of chemistry is included. Its sole purpose is to render more intelligible the tables and discussion which follows:

* Principles of Agricultural Analysis, Wiley, Vol. I, page 1.

† Oregon Bulletin No. 36, G. W. Shaw.

In all nature there are now recognized about 72 elementary substances which are known as

Elements.—*A chemical element is such a substance as cannot be separated into more than one kind of matter.* For example, iron, the smallest conceivable portion of which is just as truly iron as the largest mass.

These elements may be chemically combined in a great variety of ways to form an endless number of *compounds*, which may be defined as *substances consisting of two or more elements chemically combined in definite proportions.* The properties of these compounds differ from those of the elements of which they are composed, and from those of one another. These compounds are called *bases* or *acids* according as they possess certain characteristics.

Of these 72 elements there are but 14 which are of much value from the standpoint of agriculture. These are divided into two classes according as they do or do not form acids:

Acid Forming Elements. (Non-metallic.)	*Base-Forming Elements.* (Metallic.)
Oxygen,	**Calcium,***
Carbon,	**Potassium,***
Hydrogen,	Sodium,
Nitrogen,*	Iron,
Phosphorous,*	Magnesium,
Sulfur,	Manganese.
Chlorin,	
Silicon.	

Acids.—Now if an *acid forming element* unites with oxygen and hydrogen, or sometimes with hydrogen alone, a substance is formed which is known in chemistry as an *acid.* Thus, nitrogen combined hydrogen and oxygen forms nitric acid; phosphorous, hydrogen and oxygen form phosphoric acid.

Bases.—A *metallic* element combined with oxygen and hydrogen forms a *base*, known as a *hydrate* of that metal. Thus, calcium united with oxygen and hydrogen would be calcium hydrate. Sometimes the term base is applied to the compound of a metal and oxygen.

Salts.—The two classes of compounds above mentioned are very active in a chemical sense, and having opposite properties they always tend to neutralize each other so that neither acids nor bases are found to any great extent free in nature, but rather in the form of compounds resulting from their combination, such

* Those elements most important are indicated by black faced type.

compounds being called *salts*. It would be out of place for us to discuss here the relation existing between acids, bases, and salts further than to say that an acid differs from a salt only in having its hydrogen replaced by a metal, and that every acid has a salt corresponding to it. For example phosphoric acid consists of phorphorous, hydrogen and oxygen: now, if the hydrogen be replaced by calcium, the composition would be phosphorous, calcium, and oxygen, and the compound would be a calcium salt of phosphoric acid (calcium phosphate).

THE CONSTITUENTS OF SOILS.

From what has been said concerning the origin of soil, and the action of water and other transporting agents, it is evident that soils in general must have a similar composition. They all contain these elements combined one with another in various ways as oxids, or salts. So important is each of these elements that if any one is lacking, it matters not how abundant the supply of others, plants cannot grow. If any one of them is present in insufficient quantity plants will suffer from lack of proper nutrition.

Oxygen.—Oxygen is by far the most abundant of all the elements. It forms about one-fifth of the atmosphere, where it exists in a free and uncombined state as a *gas*. It is the vital principle of the air we breathe. It constitutes about one-half of the solid crust of the earth, and eight-ninths of all the water. In these latter forms, it exists in a state of chemical combination with other elements. It combines chemically with nearly every known element, and is especially important in building up, and destroying all forms of organic matter. In a free state it is an invisible gas, posessing neither taste nor smell. Chemically considered it is a very active substance. In all forms of burning the oxygen of the air is combining with other elements, the heat being the result of the chemical union.

In soils it is found both in a free state and combined with each of the elements named. With silicon it forms silica, or quartz, which is the chief ingredient of nearly all soils.

Carbon usually occurs in nature combined with other elements. In the soil it is a constituent of the organic matter (humus), and is also associated with calcium, magnesium and oxygen in the form of carbonates, ex. limestone. It is also combined with oxygen alone as carbon dioxide which is formed from the decay of vegetable matter and is found dissolved in the soil water. The plant obtains its carbon from the free carbon dioxid of the atmosphere.

HYDROGEN is the element which, when chemically combined with oxygen, forms water; in which form it plays its greatest part in agriculture; combined with the carbon dioxid and assimilated by the plant it forms tissue, starch and sugar. It constitutes about one-ninth, by weight, of all water; it enters into the composition of all plants and animals; it is the lightest substance known. Like oxygen, it is an invisible gas, without color, taste or odor; but unlike oxygen, instead of being a supporter of combustion, it will, itself, burn when brought into contact with a flame. It is seldom, if ever, found in a free, or uncombined, state.

SULFUR.—The element sulfur is too well known to need any detailed description. It does not occur in ordinary soils uncombined, but united with some of the metals as a sulfids or sulfates. In the former condition it is usually harmful to plants, but in the latter form it may be of considerable agricultural importance. In this form it is united principally with calcium and oxygen, as landplaster, or gypsum. Thus combined sulfur is a constituent of most soils.

CHLORIN.—In minute quantities this element is found in soils. It is always present in plants. In soils and waters it is associated with sodium as common salt.

ALUMINUM is the basis of clays and in this form serves to impart strength to soils. The clays are derived from the breaking down of feldspar, mica, and a few minerals of lesser importance. The element itself is a beautiful, white metal, very light and tough. When combined with oxygen it forms a compound known as *alumina*. It is in this form that it is separated in a soil analysis.

IRON as an element needs no description. It is a very widely distributed element, being an almost universal constituent of soil. When in the soil it is united with oxygen as an oxid which imparts the red or brown color to many soils and rocks. Yet all red soils do not owe their color to this element. The element does not enter the tissues of the plant to any great extent, but is important to plants in the formation of the green coloring matter (chlorophyl). It performs an important part in the soil by converting soluble phosphates into relatively insoluble forms and thereby protects them from being washed away. It also aids in fixing the potash and ammonia in the soil. It is also very beneficial in its physical effects usually rendering a soil easy of tillage and increasing its absorbing and retaining power for both heat and moisture.

MAGNESIUM in combination is found in nearly all cultivated soils. It resembles lime in many of its properties and is very often associated with that element. It is found in the ash of all plants, yet as a direct plant food it is of little importance, and it has little direct action on the soil.

SODIUM "is the basis of common salt and as such has a world-wide distribution. It very much resembles potassium as an element but can in no sense take its place in the life of land plants. In the form of Chili saltpeter sodium nitrate is largely used as a fertilizer, but for the nitric acid it contains rather than for the sodium." *

PROPERTIES AND FUNCTIONS OF THE MOST IMPORTANT ELEMENTS.

CALCIUM compounds are usually known as lime compounds. It is one of the commonest and most important elements of the earth's crust, of which it has been estimated to compose about one-sixteenth.† Calcium, or lime compounds, are found in most soils in a reasonable quantity, usually in the form of a carbonate or a phosphate, but sometimes, as we shall see later, as a silicate, in which form it is of less agriculture value than in either of the others. To exert its beneficial effect in neutralizing the acidity of soils produced by the natural decomposition of organic matter the lime must be in the form of a carbonate, but either of the other forms might supply a sufficient amount for plant food as which the lime is immediately concerned in the conversion of starch into cellulose (woody fibre). Professor Hilgard says: "Other things being equal the thriftiness of a soil is measurably dependent upon a certain minimum percentage of lime." Its influence on the physical condition of a soil is very marked. It tends to render stiff clay soils more porous and pulverulent, and thus more productive. It has a marked influence on the transformation of vegetable matter into humus, and in hot climates to protect the latter from excessive oxidation. In its presence much

* The Soil, King, page 81.

† Agricultural Analysis, Wiley, page 18.

smaller amounts of potash and phosphoric acid will suffice to produce remunerative crops. All these factors tend to place lime in a very important position in agriculture, and to render its determination in soils of no small interest.

Potash is the compound resulting from the chemical union of the soft, waxy bluish metal potassium with the element oxygen, for which the metal has such an affinity that it will even decompose water to obtain it. In nature it is found combined with acids, as sulfuric, carbonic, or silicic, and in several compounds containing two or more metals. Something more than its mere presence in soils is necessary for healthy plant growth for there must be a tolerably abundant supply. Its presence in considerable quantities in the ash of plants is evidence of a considerable natural supply, which is principally feldspar, mica, and a few minerals of lesser importance. One of the earliest subjects to be investigated was the relation of this substance to vegetable life. Experiments show that when potash is deficient in soils plants suffer greatly in their woody portion and in the fleshy part of their fruit. Plants use the potash in the early part of their growth, and the element suffers a retrograde movement in the plant about the time of maturity. Its function in plant economy has been the subject of much study on the part of agricultural chemists, the results of whose labors may be summarized as follows:

First. The element is essential for the assimilation of carbon, and its elaboration into starch, giving strength to the cell tissue. Thus the plant suffers greatly in its woody portion in the absence of potash in requisite quantities.

Second. It is associated with starch in its translocation from cell to cell and its transformation into sugar. Hence the size and quality of fruit is materially affected by a deficiency of potash.

Third. It is required for a proper development of fruit acids or their acid salts, so important in imparting an agreeable flavor to fruits.

Phosphorous.—In a chemically pure state phosphorous is a soft waxy, yellow solid, and extremely inflammable on account of its great affinity for oxygen. When it burns it simply unites with the oxygen of the air and forms an oxid of phosphorous, commonly called *phosphoric acid.* The element never occurs in a free state but occurs as phosphoric acid combined with lime, magnesia, or iron. It is from these phosphates that the agricultural phosphoric acid is obtained. The phosphates found in the soil are partly in forms readily utilized by plants, and partly in insoluble forms which have to be subjected to the influence of water, carbonic acid, and air before they are assimilable by plants. It is quite widely distributed in soils, but not in large quantities. That it is of extreme importance in agriculture is shown from the fact that no perfect plant has ever been produced without phosphorous in the form of a phosphate. These phosphates are only slightly soluble in water, so the quantity in the soil is only removed by the plants as it becomes available.

"Cereal crops remove about 20 pounds of phosphoric acid per acre from the soil annually, and grass crops about 12 pounds. The total phosphoric acid removed annually by the cereal and grass crops in the United States is nearly 4,000,000,000 pounds."*

As with potash plants need their supply of phosphoric acid in the early part of their growth. Wheat demands 80 per cent. of the total in the first half of the growing period. Clover assimilates practically all of its phosphorous before bloom. The function of the element appears to be in stimulating the assimilation of other mineral substances and in promoting root development. It is intimately related to the nitrogenous matter in plants for a high nitrogen content is usually accompanied by a high phosphorous content. While nitrogen and phosphorous both accumulate in the seeds of plants and pits of fruit, and neither is subject to the retrograde movement of potash, yet experiments show that the action of the two is entirely independent of each other.

NITROGEN.—This element exists free in the atmosphere of which it forms four-fifths by volume. Like its associated gas oxygen, it is colorless, tasteless, and odorless, but is a non-supporter of combustion. "It is present in soils as a constituent of humus and decaying tissues of plants and animals, from which, through the instrumentality of microscopic life there it is converted ultimately into nitric acid, which, uniting with potash, lime, or other soil ingredients forms a soluble salt taken up by the roots of plants, and is then made to yield up its nitrogen to build those nitrogeneous compounds so abundant in the tissues of animals."† Nitrogen is present in the soil in the form of nitrates.

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* Wiley's Agricultural Analysis, page 6.
† The Soil, King, page 79.

The function of nitrogen is to strengthen plants in their early growth. It favors leaf development and imparts a deep, healthy green color to the foliage. In excessive quantities it will produce a rank growth of foliage and sappy wood at the expense of fruit development and flavor. This point should be carefully noted by horticulturists and nitrogenous fertilizers should be used with caution if fruit development is desired.

TEXTURE OF SOILS.

Ere the reader has reached this point in the discussion he will doubtless have observed that the soil consists of two portions, one organic derived from the various forms of life associated with it, the other mineral consisting of sand and clay in various proportions.

The great bulk of soils is sand and clay and upon the variable amounts of these materials is based their popular classification. The sand and clay comes for the most part from the decomposition of the underlying rocks. The gradation between sandy and clayey soils are roughly expressed by such terms and distinctions as the following:

	Per cent. of clay or Impalpable matter.	Per cent. sand.
Heavy clay	75 to 90	10 to 25
Clay loams	60 to 75	25 to 40
Loam	40 to 60	40 to 60
Sandy loam	25 to 40	60 to 75
Light sandy loam	10 to 25	75 to 90
Sand	0 to 10	90 to 100

Analyses of two typical soils of the State will serve to show the component physical parts. Soil 1 is from The Dalles and represents a great extent of country. Soil 2 is one very common in the Willamette valley and was taken from the foot hills south of Eugene.

		No. 1	No. 2
(1)	Coarse sand	30.4	80.5
(5)	Sand	24.0	2.5
(3)	Fine sand	12.2	2.0
(4)	Silt or clay	33.4	14.0

In the complete decomposition of either animal or vegetable matter the resulting products are chiefly carbonic dioxid, ammonia, and water, but there is an intermediate stage in this process of decomposition—this passage from woody fibre to gaseous matter—in which the material is called *humus*. Leaf mold largely consists of humus: peat is a mixture of this humus with undecomposed vegetable matter: the "duff" soils common to the wooded lands of our coast region furnish another example.

Humus is not a definite compound but rather a mixture of several compounds whose properties and individual characteristics are not as yet understood on account of their complex nature and the difficulty of isolating them without effecting some chemical change in them. While humus is not an essential plant food yet it is a valuable storehouse of nitrogen, and materially influences the physical character of the soil. "We should think of humus as the food of microscopic life in the soil, and of the waste products of this microscopic life as a very essential part of the food of higher plants."*

Humus is especially valuable in light sandy soils since it will absorb and retain more moisture than any other soil ingredient; clay soils it materially improves by loosening and aerating. On account of its very close relation to the moisture content of soils much care should be taken to conserve and protect it, and particularly is this true in the eastern part of the State, where the continued open culture practiced in all grain farming followed by bare fallow is extremely wasteful of this important ingredient. Indeed this practice is rapidly telling on the ability of those light soils to withstand drought. It has been shown that by the practice of bare fallow five times as much humus is oxidized and destroyed as would be removed by the growth of a crop. There is no doubt but that the crop succeeding the fallow will be perceptibly increased but the ultimate effect is to get the land out of condition and very much lessen its capacity to withstand drouth.

In the Willamette valley the subject of proper drainage has a very close relation to the maintainance of humus supply, for unless this condition obtains nitrification, or the conversion of nitrogenous organic material to nitrates, cannot well take place. In speaking of this formation Dr. H. W. Wiley says: "Above the water level there is a very free access of air and even the harder parts of the leaf skeleton can be oxidized through the agency of bacteria, while under the water level there is a very limited supply of air and this oxidation cannot proceed rapidly."† On account of the high water-level the formation of humus in the soils of the Willamette valley is much impeded. There is still a

* The Soil, King, page 95.
† Wiley's Agricultural Analysis, page 61.

further reason for improving the drainage of these lands in that there are also other microörganisms which restore nitrogen to the air from the nitrates already found thus tending to decrease the store of nitrogen. Denitrifying organisms are particularly active in soils carrying a limited supply of air—soils that are "water-logged"—which fact offers another potent reason for giving more attention to drainage. The influence of these miroörganisms in producing and maintaining soil fertility is of the highest importance, for in most cases of worn soils they may be made to preclude the necessity of purchasing high-priced nitrogenous fertilizers. This process of nitrification resulting in the conversion of ammonia into nitric acid through the action of microörganisms, occurs only in the upper stratum of the soil where access of oxygen for supporting the acting organisms is greatest. The activity is of a necessity increased by the porosity of ths soil and by exposing new surfaces to action. The most recent Rothamstead experiments demonstrate that little or no nitrification occurs in the subsoil; 2-3 feet being evidently the extreme depth at which the phenomenon occurs.* The nitric acid of the soil below this depth is doubtless carried thither in the drainage or by diffusion. The depth at which nitrification may occur, however, is capable of considerable variation, not only because of the physical condition of the soil, and access of oxygen, but also on account of the character of the crop grown; leguminous plants, like the vetch and the clover, seeming to possess the property of considerably increasing not only the depth at which the transformation may occur, but also the activity of nitrifying organisms.†

There are no two factors in conserving the humus already in soils, and in aiding its development more important than good drainage, and the rational use of green manures, particularly clover.

Thus having briefly covered the general principles of soils and the function of their critical elements, we come to a more detailed discussion of the soils of Oregon. All samples have been taken according to the same directions, which were purposely made in harmony with the method employed by Dr. Hilgard for the sake of comparison (See appendix.)

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*Stockbridge's Rocks and Soils, page 138.
†Warrington, Journal Chemical Society, February, 1887.

NATURAL DIVISIONS OF THE STATE.

Owing to the topography and climatic conditions of the State, sharp contrasts in agricultural possibilities are forced upon us. The Cascade range, 150 miles from the coast, divides the State into two parts, differing from each other so much in climate as to render the terms arid and humid strictly applicable respectively to the eastern and western parts of the State. The western area of this grand natural division is subdivided by the Coast range, between which and the Cascade lies the Willamette valley. While under the term humid area, we must include the entire western part of the State, yet the geological formations of the southern part of this area are so different from those of the Willamette valley as to give rise to an entirely different character of soils, and render it necessary to give them a place by themselves. Hence the retention of the term "Southern Oregon," as popularly used, to denote that portion of the western or humid area south of Lane county, is very apt for our present purpose. The area east of the Cascade range is so radically different from the humid area of the western part of the State as to bring about distinctly different soil conditions, but not different from those of other parts of the world having a scanty rainfall. It is in this sense of limited rainfall that the term arid is used. It does not in the least imply that the lands are not of equal value with those of the humid area. Indeed, it is true that this same "arid" soil is, from natural causes, likely to be the very richest in plant food.

With these few remarks as to the natural divisions of the State, I proceed to discuss some of the more prominent features of the soils as they appear from an examination of a considerable number of samples.

WILLAMETTE VALLEY.

The Willamette valley, embracing about 5,000,000 acres, is by far the largest valley in the State. It is about 130 miles in length by 60 in width and extends from a low range of hills on south (Calipooias) to Portland on the north. To show how well watered is this valley it may be stated that over 40 streams feed the Willamette in its course, and the stream is navigable for about 100 miles from its mouth.

The soils of this valley may be classified under two general heads, viz: those of the foot hills and those of the bottom lands extending on each bank of the river. The former comprise a belt of rolling land extending nearly around the prairie and merging into the mountains. The prevailing soils are of basaltic origin mixed with more or less sandstone soil on the west side. The purely basaltic soils are mostly confined to the hills where they are generated. All the "bottom land" is of an alluvial nature and varies greatly in depth, from a few inches to many feet. It is composed of the washings from the hills and consists, as one would infer from the above, of decomposed volcanic matter, somewhat basaltic in nature, mixed with sand and a large amount of vegetable mould or "humus," the last named substance being the more abundant in this portion of the State because of the humid climate.

It is a fact noticed in Italy long since, and borne out by experience in this northwest, that the soils of volcanic origin are of unsurpassed fertility. The basalt from which much of the soil in Oregon is derived is not like most rocks in respect to its make-up for it contains, from the very nature of the case, the fertilizing ingredients of a combination of rocks. Basalt is a complex mineral and a type of basic rocks. It is a very dark, almost black, rock, exceedingly hard and quite heavy; mineralogically it is made up of plagioclase (a soda-lime feldspar) augite, and olivine; it also nearly always contains more or less magnetic iron ore and other minerals. Chemically the rock contains silica, lime, potash, soda, magnesia, oxids of iron and manganese, and alumina. There is one quite notable feature as to one of the mineral ingredients of basalt—augite—that it not infrequently contains considerable phosphoric anhydride (P_2O_5), occurring in a crystalline form as apatite. In spite of the fact that some of the books published state that basalt forms soil very slowly, yet the rocks are really fragile and short lived. They appear to be dense and lasting, but being complex in structure and containing a considerable amount of protoxid of iron, which is capable of further oxidation, and this quite rapidly, forming a sesqui-oxid, the cohesion of the mineral is loosened and the rock breaks up. At the foot of every basaltic cliff is found a pile of debris and all over the basalt country this crumbling proceeds regularly and comparatively rapidly.

The formation of this immense quantity of basalt was from the great laval overflow, and the lesser and subsequent ones, which covered the whole of northern California, a greater part of Oregon, Washingto and Idaho, and extended into Nevada. Some of the lava beds formed at this time show a depth of 3000 feet or more. This then is briefly the source of the soils of the Willamette valley.

LIMITS OF FERTILITY.

In the following pages only those elements which are of chief importance in having often to be replaced in the shape of commercial fertilizers, will be considered, viz., lime, potash, phosphoric acid and nitrogen (humus). Just what constitutes a sufficiency of these materials for successfully growing a crop will differ somewhat with the nature of the crop, and *very largely with the physical conditions of the soil.* Prof. Hilgard, than whom no one is more competent to judge, gives the following as to the minimum percentages for a thrifty growth of green crops:

"LIME.—0.10 per cent. in the highest sandy soil; 0.25 per cent. in clay loams; 0.30 per cent. in heavy clay soils, and it may rise with advantage to one or two per cent. as a maximum. Beyond the latter figure it seems in no case to act more favorably than a less amount, unless it be mechanically."

"PHOSPHORIC ACID.—In sandy loams, 0.25 per cent. when accompanied by a good supply of lime. The maximum found in the best Mississippi table lands was 0.25 per cent.; in the best bottom land of the same region, 0.30." His investigation in connection with the Northern Pacific survey also showed that this ingredient was more abundant in the soils of Oregon and Washington than in the soils of California.* In the basaltic soils it may even run as high as .30 or more. In sandy loam, .0.1 per cent., when accompanied by a fair supply of lime, secures fair productiveness for from eight to ten years; with a deficiency of lime, twice that percentage would only serve for a similar time."

"POTASH.—The potash percentage of heavy clay upland soil and clay loams ranges from about 0.8 to 0.5 per cent.; lighter loams from 0.45 to 0.30; sandy loams below 0.30 and sandy loams of great depth may fall below 0.10 consistent with good productiveness and durability. Virgin soils with a less percentage than .06 seem in most cases to be deficient in available potash. * * * Sometimes, however, a soil very rich in lime and phosphoric acid, shows good productiveness, despite a very low potash percentage."

The same author says in another article that—

"No virgin soil having .50 per cent., or over of potash will wear out first on that side of the store of plant food; and much less will suffice in the presence of much lime and humus."

"HUMUS.—This is of great interest to us since it is the storehouse of the nitrogen supply and its determination serves as a measure of the nitrogen. In oak uplands of the cotton States the range is usually between .70 and .80 per cent.; in the poorer sandy soils from .40 to .50 per cent.; in black calcareous 1.2 to 2.80 per cent. In western Oregon it is not uncommon to find 3 and even 6 per cent."

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*Cal. Expt. Station Report, 1888.

ANALYSIS NO. 629--SOIL FROM MULTNOMAH COUNTY.

Coarse material > .5 m.m	35.50
Fine earth	64.50

ANALYSIS OF FINE EARTH (AIR DRY).

Insoluble matter	60.65
Soluble silica	11.12
Potash (K_2O)	.25
Soda (Na_2O)	.33
Lime (CaO)	1.27
Magnesia MgO	1.23
Manganese (Mn_3O_4)	
Iron (Fe_2O_3) } Alumina (Al_2O_3) }	12.24
Sulfuric acid (SO_3)	
Phosphoric acid (P_2O_5)	.40
Water and organic matter	12.16
Total	99.55
Humus	2.60

Sample No. 629 was taken near Overton Park, about 3 miles east of Portland, to a depth of 2½ feet. In other localities this type of soil is called "shot-land." (See Washington county.) The soil is underlaid by gravel, which insures it good natural drainage, and it represents an extent of country about 50 miles square, the general lay of which is level. The natural growth reported is fir, vine maple, dogwood, and wild cherry. Native strawberries are also abundant. The report states that fruit has been planted with good success on this character of soil in the same locality. Judged according to the standards previously given, it would appear to be a most excellent "all around" soil. The lime supply is superior to that of most soils of the Willamette valley. Were it not for the abundance of this ingredient the soil might be considered weak in potash, but the potash present, on account of the lime, is likely to be quite available. Its phosphoric acid and its humus content is each most excellent. Its weakest point is potash, but it could by no means be called deficient in this ingredient. The humus supply is greater than in similar soils in Washington county as will be seen by comparing the analyses.

SOILS FROM WASHINGTON COUNTY.

COMPONENTS.	No. 1 C. Forest Grove. H. Buxton.	N. 1 D. Ditto.	No. 1 F. Gales Creek. Anson Powell.	No. 1 G. Ditto.	No. 1 H. Ditto.	No. 1 L. Fir. B. M. Collins.	—— Beaverton. No name.	No. 425. Gales Creek. J. H Bamford.	No. 449. Buxton. J. H. Rinck.	No. 2 N. Ditto.	No. 623. Ditto.	No. 624. Ditto.
Character of soil	Loam	Red clay	Shot-land	Shot-land	Shot-land	Shot-land	Beaver-dam	Shot-land	Bottom land	Sandy loam	Beaver-dam	Sandy loam
Coarse material > .5 m m	1 00	3 00	51 94	34 00	19 00	33 00	....	47 20	5	1 38	40 74	8 43
Fine earth	99 00	97 00	48 06	66 00	81 00	67 00	....	52 80	94	98 62	59 26	91 57
Capacity for water	53 40	8 00	50 81	40 80	50 00	45 00	....	40 00	38	48 00	44 00	52 00
Hygroscopic moisture (15° C.)	5 00	1 42	3 30	6 50	4 72	8 30	....	....	....	....	....	....
ANALYSIS OF FINE EARTH.												
Insoluble matter	76 19	75 06	65 89	67 40	67 99	63 62	73 40	75 00	73 36	70 98	63 48	82 59
Soluble silica	4 49	3 76	5 82	5 18	3 22	9 74	....	5 16	3 33	4 20	5 31	24
Potash (K_2O)	03	16	12	28	26	11	18	02	11	51	17	23
Soda (Na_2O)	01	....	06	05	07	08	57	03	08	33	19	14
Lime (CaO)	34	63	75	13	76	1 47	1 49	82	50	49	1 13	04
Magnesia (MgO)	1 71	1 18	13	90	71	1 27	26	85	....	71	38	1 45
Manganese (Mn_3O_4)	22	21	38	04	....	22	....	50	....	....	....	16
Iron (Fe_2O_3) } Alumina (Al_2O_3) }	8 76	7 58	17 50	17 67	18 13	12 88	7 28	9 81	13 46	12 07	14 08	9 34
Sulfuric acid (SO_3)	....	05	....	08	08	04	28	....	06	05	15	01
Phosphoric acid (P_2O_5)	03	32	09	34	34	30	23	04	25	54	12	21
Water and organic matter	8 51	11 63	9 81	7 98	8 74	9 80	10 95	8 90	8 45	10 58	9 38	4 99
Total	100 29	100 58	100 79	100 03	100 30	99 54	99 86	101 11	100 10	100 40	100 00	100 00
Humus	....	20	1 87	1 76	....	32	....	58	1 95	3 40	2 95	1 42

1 C.—The average depth of the soil is about 3 feet. It is a mixture of decomposed soapstone with some sand and feldspar. It is a gray loam which darkens considerably on wetting and becomes fairly plastic on kneading. In the analyses of the soil the most striking feature is the very low percentage of potash and phosphoric acid and were these not in a very available form it would be considered deficient in these ingredients. That these ingredients are in an available form is shown by the fact that soil from the same general locality has produced good crops for a long series of years. The high percentage of magnesia is consistent with the soil's origin. Its lime content is fair for a soil of this character, but good results would probably follow an application of a mixture of lime and potash, or still better, perhaps, a complete fertilizer.

1 D.—This is a stiff red clay and very waxy. The dry lumps are almost impossible to crush and darken only slightly on moistening. To render this soil suitable for crops it should be drained. It seems to be fairly well supplied with mineral food, but is quite weak in humus. The addition of organic matter in the shape of barnyard manure would much improve its physical condition and at the same time add much to its store of nitrogen (humus). Straw could be worked into this soil to advantage.

1 F., 1 G., 1 H., 1 L., No. 425.—These are all red soils which characterize quite an area in Washington county. They are known locally under the name of "shot-land." No. 425 is notably deficient in both phosphoric acid and potash and is not strong in humus. The lime supply is about the average for western Oregon and would be considered fair. The soil would doubtless respond well to fertilizers containing all three of the critical elements. No. 1 F is weak in both potash and phosphoric acid but well supplied with lime and humus. Its weakness is in the same points as No. 425, with the exception of humus, with which ingredient 1 F is very well supplied.

No. 449.—This sample may be classed with the grey clay loams characterizing the bottom lands of the Willamette valley. This sample was taken from 8–10 inches in depth on the Dairy Creek bottom and had never been cultivated. The natural growth is reported to be white fir and maple. On wetting the soil be-

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The different style of numbering is due the adoption of consecutive numbers to designate sample in the laboratory.

comes a deep black, and somewhat sticky on kneading. It is rich in phosphates but weak in potash. It carries a high iron content for a soil of this character, and doubtless the phosphoric acid is there combined. Gypsum would probably produce good results on this soil in setting free potash inasmuch as the natural lime supply is not strong. The humus supply is good, but if gypsum is applied it would be best used in connection with clover.

No. 2 N is a sandy loam of light color, which changes to a light brown on wetting, but the soil does not become sticky. It is a soil of excellent texture and is a type of soils prevalent on the lowest creek bottoms in the same general region as No. 449. The physical analysis shows the soil to be composed of very fine material. This soil is abundantly supplied with potash and has an exceptionally good phosphoric acid content, and is rich in humus. It is an instance which shows that the color of soils is not always indicative of the humus content, for the light colored soils often carry quite heavy percentages of humus and particularly is this true of certain red soils. The fertility of the soils would be improved by the addition of lime.

No. 623 is a typical soil of this same region and usually occurs in strips separated by the "shot-lands." While the soil is black in color it seems to have been originally composed of the same material as the red soils above mentioned. It is marked by the same characteristics as the shot-lands except so far as the humus or organic matter is concerned of which ingredient it carries about twice as much as the average of these lands. The lime content is most excellent which will help out an apparent deficiency in potash.

No. 624.—This is another of the sandy loams of this region, but of coarser texture than that described above. A very noticeable feature of this soil is the extremely small amount of "soluble silica" as well as a great paucity in lime. The soil would be much improved by liming. Applications of wood ashes would no doubt produce excellent results. The use of either of these materials would not only improve the chemical nature of these soils but would also tend to give them more body. Recent experiments have shown that not infrequently is it the case that wood ashes are fully as valuable for the lime present as for the potash.

ANALYSIS NO. 447—SOIL FROM CLACKAMAS COUNTY.

Coarse material > .5 m.m.	25.50
Fine earth	74.50
Capacity for water	36.00

ANALYSIS OF FINE EARTH (AIR DRY).

Insoluble matter	75.96
Soluble silica	4.00
Potash (K_2O)	.29
Soda (Na_2O)	.36
Lime (CaO)	.59
Magnesia (MgO)	.80
Manganese (Mn_3O_4)	
Iron (Fe_2O_3) / Alumina (Al_2O_3)	12.27
Sulfuric acid (SO_3)	.04
Phosphoric acid (P_2O_5)	.31
Water and organic matter	5.28
Total	99.93
Humus	.55

No. 447 was sent from Scappoose by Mr. J. C. Johnson. It is similar in appearance to the "shot-lands" previously described and should be classified with them. The soil is about 16 inches deep, underlaid by clay, and this in turn by gravel. The natural growth is fir, vine maple and hazel. The soil is said to produce good clover and other staple crops. The lime supply of this soil is fair, its potash supply moderate, its phosphoric acid excellent, and humus very poor. The soil would be much improved by the growing of clover or other green crops, reinforced by applications of gypsum to liberate the plant food present of which there seems to be a fair quantity but probably not in as available a condition as is desirable.

SOILS FROM YAMHILL COUNTY.

ANALYSIS.	No. 768.	No. 769.
Coarse material > .5 m.m.	3.00	5.50
Fine earth	97.00	94.50

ANALYSIS OF FINE EARTH (AIR DRY).

	No. 768.	No. 769.
Insoluble matter	74.02	73.10
Soluble silica	2.45	2.11
Potash (K_2O)	.26	.38
Soda (Na_9O)	.54	.65
Lime (CaO)	.63	.43
Magnesia (MgO)	.63	.53
Manganese (Mm_3O_4)	Trace	Trace
Iron (Ne_2O_3) / Alumina (Al_2O_3)	11.22	10.01
Sulphuric acid (SO_3)	Trace	Trace
Phosphoric acid (P_2O_5)	.23	.76
Water and organic matter	11.25	12.33
Total	101.23	100.40
Humus	3.57	3.30

Nos. 768 and 769 are both samples of the grey clay loams of the Willamette valley. Underlaying these soils there is a "hardpan" at a depth of about 2½ feet. In this locality the ground is rolling and is similar to sample for six miles square. The natural growth is oak, maple, wild rose and blackberry. Analysis shows the soils to be well supplied with plant food and particularly is this true of humus. Ground limestone could be applied to these soils to good advantage, or, perhaps better, air-slacked lime.

SOILS FROM MARION COUNTY.

COMPONENTS.	No. 2 A. J. Vorhees, Salem.	No. 2 B. Ditto.	No. 426. F. R. Smith, Salem.	No. 626. G. W. Dimick, Hubbard.	No. 622. E. K. Shaw, Brooks.	No 628. S. R. Burford, Salem.	No. 628½. Ditto.	No. 619. Oregon Land Co., Salem.	No. 619½. Ditto.
Character of soil	Beaver-dam	Subsoil	Redhill	Prairie	White land	Redhill	Redhill	Redhill	Subsoil 619
Coarse material 7.6 m.m.	9 17	35 63	28 88	35 00	62 00	5 00	....	19 00	....
Fine earth	90 83	64 36	71 12	65 00	38 00	95 00	....	81 00	....
Moisture absorbed at 15° C	....	....	....	....	....	....	....	....	....
Capacity for water	48 00	50 00	42 00	....	....	....	....	....	....
ANALYSIS OF FINE EARTHS.									
Insoluble matter	51 53	....	68 48	62 23	} 72 32	{ 72 04	71 99	43 90	} 52 23
Soluble silica	21 88	9 40	4 38	13 00		4 94	4 18	9 26	
Potash (K_2O)	94	04	47	12	46	48	52	50	62
Soda (Na_2O)	66	03	33	65	19	31	20	38	....
Lime (CaO)	75	10	40	95	Trace	32	34	35	
Magnesia (MgO)	97	91	96	62	05	50	33	22	28
Manganese (Mn_3O_4)	09	05	....	....	Trace	....	....	....	....
Iron (F_2O_3) } Aluminum (Al_2O_3) }	15 11	12 20	14 78	12 32	12 21	14 70	15 58	23 72	24 84
Sulfuric acid (SO_3)	....	....	....	....	....	....	....	....	....
Phosphoric acid (P_2O_5)	13	28	63	29	07	19	22	35	30
Water and organic matter	8 50	7 60	10 19	10 29	14 70	7 75	8 38	20 08	23 12
Total	100 56	100 37	99 72	100 57	100 00	101 28	101 74	99 74	101 49
Humus	3 50	....	52	5 42	2 73	4 53	3 11	4 27	3 16

No. 2 A is a good type of the beaverdam soil which is common in the vicinity of Woodburn. Attention is called to its high capacity to absorb moisture in connection with its high percentage of humus. Its potash supply is *very* abundant; it is well supplied with lime, but deficient in phosphoric acid. The lime and potash would in a measure compensate for this deficiency. The humus supply is excellent. Bonemeal could doubtless be used to advantage to bring up the phosphoric acid supply gradually. If well drained it would make a most excellent fruit soil.

No. 2 B is the subsoil of 2 A taken from 2–3 feet below the surface. It is of an entirely different character from the soil proper.

No. 426 is a red hill soil from near Salem. No data accompanies the sample. In appearance and physical action it is very similar to No. 619, although its phosphoric acid content is much higher and its humus percentage much lower. It is poor in lime and rich in magnesia. Clover crops would no doubt materially improve the soil as would also applications of gypsum. It would prove a good soil for fruit.

No. 626.—This soil is a brown prairie loam of great depth, the soil having been bored to a depth of 300 feet without reaching rock. It is the soil of several townships in the locality of S. W. ¼ of Sec. 35, T. 4 S. 1 W. The sample was taken to a depth of 2 feet. Water is found at a depth of about 20 feet and is hard, which would be expected from the high lime and magnesia percentages. The land is easily cultivated. It contains enough of the reddish soil from the neighboring hills to give it a tinge of that color. The soil is too weak in potash to be a lasting one for pitted fruits, although the lime supply will assist in the production of good crops for a number of years. Both phosphoric acid and humus are abundant. The soil will first need potassium fertilizers. Ashes could be used with profit on such soils as the one under consideration.

No. 622.—This is a prairie soil from near lake Labish. The sample was taken to a depth of 2 feet. Water is found in the locality at a depth of 20 feet. There are many hundreds of acres of similar land along the line of the O. & C. railroad. In this sample there is sufficient material from the hill lands intermingled with the purely bottom soil to impart a distinctly reddish tinge to the sample. Most of the soils of this character are a little lighter in color. In the early days orchards were placed on this soil but they have now gone to decay. The soil is very flat and is not well drained. It is well supplied with potash and humus but deficient in phosphoric acid, a fact which is usual with soils of this valley. It needs drainage at present more than fertilizers.

No. 628 and 628½ are both samples of red hill land of Marion county. The two samples were taken about 150 feet apart. Their color is dark reddish brown—a little darker than most soils of the same region. The texture of the soil is good. The lime and the potash supply are fair for a soil of this texture, but would be considered low for a soil of a heavier type; phosphoric acid is excellent as well as humus, but the high iron-plus-alumina would indicate the former not to be very available. Applications of lime would probably be followed with good results.

No. 619.—This is taken from S. E. ¼ of N. E. ¼ of Sec. 27, T. 8 S., R. 3 W. near the town of Rosedale. It is a typical red hill soil "underlaid by a soft porous rock which apparently gives rise to the soil." The natural growth is that previously described for similar soils. Water is found at a depth of about 13 feet. Soils of this character have yielded excellent crops of wheat for many years in succession. About 2000 acres of such soils in this vicinity have been planted to fruit and with good results. Chemical analysis shows that these will be very lasting soils for all critical elements are present in abundance, although the very high iron content would indicate that much of the phosphoric acid is insoluble. Attention is also directed to the very high "water and organic matter." Of this amount 6.36 and 7.52 per cent. respectively was hygroscopic moisture, leaving a large part of it for combination—probably as hydrated alumina. No. 619½ is subsoil of 619.

Polk county has an area of about eight hundred square miles. Its soil conditions in general are the same as characterize the larger part of the Willamette valley. Its bottom lands are a deep grey loam which is very productive of cereals and is well represented by soil No. 1 K, but the fertility of these soils hardly exceeds that of the hills which are red in color but of different physical texture from the red hills of Washington and Clackamas counties previously described.

SOILS OF POLK COUNTY.

COMPONENTS.	No. 409. J. H. Emmett. Eola.	No. 424. J. H. Emmett. Eola.	No. 1 K. A. W. Lucas, Monmouth.	No. 625. Frank Butler, Falls City.
Character of soil	Hill	Subsoil (409)	Clay Loam	Redhill
Coarse material > .5 m m	41 34	40 57	18	45 30
Fine earth	59 66	59 43	99 82	54 70
Hygroscopic moisture (15° C.)	....	5 68	7 76	....
Capacity for water	32 00	40 00	53 00	44 00
ANALYSIS OF FINE EARTH [AIR DRY].				
Insoluble matter	56 66	35 20	74 02	71 80
Soluble silica	12 59	15 35	6 44	7 97
Potash (K_2O)	02	39	24	47
Soda (Na_2O)	01	03	06	20
Lime (CaO)	2 01	75	60	56
Magnesia (MgO)	02	87	55	79
Manganese (Mn_3O_4)	Trace	04	05	....
Iron (Fe_2O_3) } Alumina (Al_2O_3) }	25 22	30 84	8 90	2 71
Sulfuric acid (SO_3)	03	....	11	....
Phosphoric acid (P_2O_5)	02	47	33	22
Water and organic matter	4 26	15 08	8 06	15 28
Total	100 84	99 02	99 36	100 00
Humus	3 90	1 81	7 86	6 59

No. 409 is a sample taken from three miles west of Salem, near Eola hills, from 1 to 8 inches deep. The soil carries much iron to which the red color is undoubtedly due. The sample is deficient in both phosphoric acid and potash, but carries an abundance of lime. It is not probable that this sample is typical of the hills, except so far as iron is concerned, for these hills have been found to produce well under continuous cropping for many years in succession. The humus content is high. Probably applications of gypsum or sulfate of potash would be followed by good results on this soil.

No. 1 K.—This is an ordinary clay loam. The field from which the sample was taken is sufficiently rolling to render the soil self draining, which fact makes the soil a typical one of the bottom soils of this valley when well drained. Its water capacity is high, ond on wetting the soil becomes quite dark. Phosphoric acid is high, potash and lime both low, and humus very high, which last named fact no doubt accounts for its high water capacity and explains the remark made in the accompanying report that "it holds moisture very well."

No. 625 is a red hill soil of excellent texture. The red color of the soil is evidently not due to the presence of iron for this element is present in only limited quantities. Lime is deficient in the soil, but all other ingredients are abundant. The soil would be much improved by applications of lime carbonate. Both physically and chemically the soil is an excellent one.

Benton county is one of the leading agricultural counties of the State. Her soils resemble those of other portions of the valley, particularly those of Polk. The prairie bottoms are of a rich dark loam. The hills are of a reddish soil of excellent texture and very well drained, with the exception of here and there spots of adobe to be discussed later. There is quite a body of "white land" found in various low lands of the county, but this character of soil is not confined to the limits of this county. This heavy whitish clay is destitute of natural drainage, but when artifically drained it rapidly assumes the appearance and texture of the grey loam of the valley. Its present condition is probably the result of wretchedly bad drainage. The bottom soils are made up from the washings from the hills added to the clays and loams from the former sedimentary deposits.

SOILS OF BENTON COUNTY.

COMPONENTS.	No. 1 I. College Farm, Corvallis.	No. 1 J. Ditto.	No. 597. College Campus, Corvallis.	No. 410. Ditto.	No. 411. Belfountain Prune Company, Monroe.
Character of soil	Adobe	Clay	Clay loam	White, un-drain'd	Redhill
Coarse material > .5 m.m	2 25	1 75	5 60	16 50	....
Fine earth	97 75	98 25	94 40	83 50	....
Moisture absorbed at 15° C	....	....	....	....	....
Capacity for water	56 00	44 20	60 00	....	....
ANALYSIS OF FINE EARTHS. [AIR DRY]					
Insoluble matter	38 91	72 70	76 65	70 26	65 74
Soluble silica	16 14	5 93	9 25	5 53	4 94
Potash (K_2O)	11	47	33	06	21
Soda (Na_2O)	03	24	08	07	40
Lime (CaO)	1 60	1 60	89	66	46
Magnesia (MgO)	1 78	1 03	80	....	05
Manganese (Mn_3O_4)	08	10	15	04	01
Iron (F_2O_3) / Alumina (Al_2O_3)	23 21	9 23	8 08	13 51	12 56
Sulfuric acid (SO_3)	....	03	20	05	02
Phosphoric acid (P_2O_6)	01	05	25	03	34
Water and organic matter	17 44	8 00	3 56	10 13	14 82
Total	99 31	99 38	100 24	100 34	99 55
Humus	1 80	7 64	....	1 22	5 96

The analyses of Benton county soils given below are from representative samples and may be taken as showing the general composition of the respective kinds.

No. 1 I is a sample of adobe taken from the college farm. There are considerable areas of soil of this character scattered throughout the Willamette valley and southern Oregon. The soil is underlaid by a stiff clay. These adobe soils become exceedingly sticky when wet and are very difficult to work—in fact it is well night impossible to work them unless taken at exactly the right condition of moisture. If the soil is thoroughly tilled it retains moisture well. The main difficulty with this land lies in its poor drainage. If some inert material could in some way be worked into the soil it would render it materially easier to work. The tillability of the soil would be greatly improved by as much lime as could be afforded. This sample contains a low percentage of potash, but is exceptionally high in soda and magnesia percentages. Its proportion of lime is most excellent, which seems to be a characteristic of such black soils, noticed in California as well as here. The soil is fair in phosphoric acid, considering the high humus supply, and while the potash lasts should produce well if given the most thorough tillage. No permanent improvement in this soil is possible until it is thoroughly underdrained.

No. 1 J is a heavy clay soil, the coarse material of which consists almost wholly of organic matter, as sticks, etc. It is rich in potash but deficient in phosphoric acid, and contains but a limited quantity of lime.

No. 597 does not differ from other clay loams of the valley in the physical characteristics. There are thousands of acres similar to the sample in this and adjoining counties. This sample is well supplied with both potash and phosphoric acid as well as with lime and has a high water capacity. Experience has already demontrated it to be a very lasting soil the reason for which is evident in the analysis.

No. 410 is a typical "white-land" sample taken from a very wet undrained portion of the college campus. The soil examined is deficient in both potash and phosphoric acid, and for a bottom land not strong in humus. The soil is as poor as can well be found and well illustrates the effect of continued leaching of the grey loams. This type of soil when properly drained rapidly takes on a darker color, and improves in quality under proper treatment, which fact is well shown on the portions of the college campus which have been underdrained. There are thousands of acres of such land in Benton and adjoining counties which could be brought into good physical condition by properly underdraining associated with applications of lime and green manures, some of the chemical effects of which have been previously discussed (See page 14). The physical effects are, however, no less important than the chemical, and these may be summarized as follows:

First, it renders a clay soil more friable.

Second, it makes the soil warmer during the wet season by lessening the evaporation of water.

Third, it renders the soil more moist during the summer and therefore more able to withstand drouth.

No. 411 is a sample of red-hill soil from near Monroe. It is a soil of most excellent texture and presents ideal condition for fruit growing. The phosphoric acid supply is most excellent; the potash fair, but it is weak in lime. The addition of gypsum from time to time would improve the soil by not only adding lime gradually but also by setting free potash otherwise inert. On this soil is located one of the most flourishing prune orchards

Of Linn county there are only about 1,300 square miles that are suitable for agricultural purposes. "The arable portion of the county is about evenly divided into prairie and rolling land. The prairie is not a dead level, but slightly undulating, affording plenty of slope for good drainage to the Willamette river which bounds the county on the west along its whole length. The soil of the prairie lands is a rich, dark, clayey loam, of the general character of the whole Willamette valley." For the most part the soils are sandstone and basaltic. About the Santiam country the formations are porphyritic and granitic which are a contiuation of similar rocks to the north and south--a part of the same that outcrops on the west of the Cascades. Only two soils have been analyzed from this county.

1 W.--This is a light loam, black in color, from 18 to 24 inches deep, with a subsoil about 2 feet deep. The soil grows fir, maple, oak and ash. As will be seen it carries a high percentage of lime and clearly shows a lime vegetation. It has a high moisture coefficient and evidently has good natural drainage. The soil should be easily worked and though the potash is not high, yet with the heavy percentage of lime it is fairly supplied and with thorough tillage is not apt to be deficient in this quarter. It is an excellent all around soil.

SOILS FROM LINN COUNTY.

COMPONENTS.	No. 1 W. John Withers. Lebanon.	No. 643. J. C. Standish. Halsey.
Character of soil	Black loam	Beaver-dam
Coarse material > .5 m.m	22 90	50
Fine material	77 10	99 50
Capacity for water	44 00	--------
Hygroscopic moisture	7 55	--------
ANALYSIS OF FINE EARTH.		
Insoluble matter	57 82	64 25
Soluble silica	7 23	6 45
Potash [K_2O]	15	39
Soda [Na_2O]	07	63
Lime [CaO]	3 51	55
Magnesia [MgO]	21	71
Manganese [Mn_3O_4]	12	Trace
Iron [Fe_2O_3] / Alumina [Al_2O_3]	16 89	15 09
Sulfuric acid [SO_3]	02	Trace
Phosphoric acid [P_2O_5]	11	40
Water and organic matter	13 07	11 47
Total	99 20	99 92
Humus	1 88	3 60
Soluble phosphoric acid	09	--------

No. 643 is a soil of limited area but occurs in a number of scattered spots. It is "from a basin formerly filled with water in the winter," but becoming dry in the summer, "has been underdrained for three years." The soil is underlaid by a yellow clay at a depth of about 10 inches and this in turn by a blue clay at about 30 inches. The natural growth is ash, wild rose, and swamp grasses. Chemically the soil is abundantly supplied with all the essential constituents, and if well drained is likely to prove a very lasting soil. Its high humus content will render it retentive of moisture. Fruit would do well upon this soil if well underdrained, particularly pears.

SOILS OF LANE COUNTY.

COMPONENTS.	No. 1 V. J. G. Stevenson, Eugene.	No. 454. H. C. Perkins, Lewellyn.
Character of soil	Sandy loam	Adobe
Coarse materia > .5 m.m	5 70	32 97
Fine earth	94 30	67 21
Moisture absorbed at 15° C	2 00	......
Capacity for water	50 00	46 00
ANALYSIS OF FINE EARTH [AIR DRY].		
Insoluble matter	63 02	52 68
Soluble silica	8 77	6 85
Potash [K_2O]	09	19
Soda [Na_2O]	07	09
Lime [CaO]	60	65
Magnesia [MgO]	27	46
Manganese]Mn_3O_4]	02	23
Iron Fe_2O_3] / Alumina [Al_2O_3]	15 90	18 56
Sulfuric acid [SO_3]	02	04
Phosphoric acid [P_2O_5]	16	13
Water and organic matter	10 51	20 12
Total	99 43	100 00
Humus	1 21	5 59

Lane county, an area of about 7,000 square miles, with an average breadth of about 50 miles, being about three times this distance in length. About three-fourths of this county is hilly and mountainous. The table or hill lands bordering the valleys seem to be quite fertile, and produce well when brought under cultivation. No. 1 V is a soil of this type, but whether all will show as low a content of potash is somewhat doubtful. The county is abundantly supplied with streams and springs. Considerable swale land is found in some parts of the county, mainly white land, but with good drainage this can be made productive.

No. 1 V is a sandy loam which covers several sections in the foot-hills south of Eugene. Farther up the hills the soil becomes coarser and is underlaid with soft sandstone, which crumbles on short exposure. The vegetation is oak and wild grasses. The soil evidently has a good natural drainage and is easily worked. The mechanical separation of the soil by an elutriating apparatus gave the following result:

Coarse sand	80.5
Sand	2.5
Fine sand	2.0
Silt or clay	14.0

The dry lumps crush easily between the fingers and the soil does not become very sticky when wet. It is a soil that has been planted to fruit considerably of late. The physical condition of the soil would seem to warrant this, but the low percentage of potash would indicate that for the best results this ingredient will be needed in a few years. Experiments with potash on this soil have resulted in an appreciable increase in the yield of corn.

No. 454 is an adobe soil similar in its texture to sample No. 1 I from Benton county, but differs somewhat in its composition. The notes upon that sample are equally applicable here. This particular sample is moderately supplied with potash and phosphoric acid, but very rich in humus, as might be expected, and is well supplied with lime.

There are two classes of soil that commonly pass under the term "adobe" in each of these sections—one a soil sour on account of an excessive amount of organic matter, and consequently after neutralizing the acidity by applications of lime this soil is as easily handled as most others. The soil is well supplied with plant food and is likely to be durable. The other passing under this name is an intensely tenacious black soil, rich in organic matter and usually in other plant food, being weakest in potash. *It is impossible to treat this satisfactorily except by tile drainage.* When so drained it forms a most excellent soil for fruit and other crops. In its present condition it is not at all suited to fruit, although pears, and possibly some varieties of apples, might be placed upon it, after it has once been well cultivated, if kept in excellent tilth for an inch or so. The first cultivation, however, is difficult to secure for it must be made at exactly the right time. Mulching would be beneficial to prevent rapid surface evaporation which causes compacting and cracking. Straw could be utilized to good purpose in mulching this land. *No permanent remedy can be expected except by underdraining.**

SOUTHERN OREGON SOILS.

There are two prominent valleys included in this area within which prunes are grown to a greater or less extent, the Rogue

*Bulletin No. 45, Oregon Experiment Station, G. W. Shaw.

and the Umpqua river valleys. On account of the limited amount of work done upon the soils of this area it is not possible to present data with so much certainty as in the case of Willamette valley soils.

The characteristic soil of the southern area seems to be a reddish clay, which terminates in the high plateaus. The characteristic dark loams, resulting from the decomposition of carbonaceous slates, occur in abundance throughout the valleys. Granite soils are also a common feature of the Rogue river valley.

SOILS FROM DOUGLAS COUNTY.

COMPONENTS.	No. 618. J. M. Donnell, Wilbur.	No. 1 X. J. D. Wilson, Yoncalla.
Character of soil	Red land	Sandy loam
Coarse materia > .5 m.m	60 00	45.40
Fine earth	40 00	54 60
Moisture absorbed at 15° C	......	1 24
Capacity for water	......	42 00
ANALYSIS OF FINE EARTH [AIR DRY].		
Insoluble matter	78 32	39 58
Soluble silica	8 14	10 43
Potash [K_2O] }	1 27	{ 44
Soda [Na_2O] }		{ 26
Lime [CaO]	13	2 05
Magnesia [MgO]	......	42
Manganese]Mn_3O_4]	08	08
Iron Fe_2O_3] }	9 02	29 45
Alumina [Al_2O_3] }		
Sulfuric acid [SO_3]	02	01
Phosphoric acid [P_2O_5]	28	16
Water and organic matter	2 74	17 21
Total	100 00	100 09
Humus	3 28	1 30

Douglas is the most northerly of the group of counties comprising the district of Southern Oregon. It has an area of 4,900 square miles, of which about 300,000 acres are under cultivation. There are two principal valleys in this part of the State, that of the Umpqua and that of the Rogue river. The climate in these areas is mild and the average precipitation is about 35 inches. In the valleys the soil is alluvial, deep and highly productive. The benches and hills have also a soil rich and deep and well adapted to fruit culture. The Umpqua valley is one of the finest fruit sections of the State.

No. 618 is from N. E. ¼ of Sec. 12, T. 26 S. R. 5 W., near the town of Wilbur. The sample is of the characteristic red soil of the region and was taken to a depth of 2 feet. Water is found at about 30 feet and is soft. The natural herbage is oak, fir, and "poison oak." The soil has been quite extensively set to fruit. The soil would seem quite well adapted to this industry, although its lime supply is weak. Humus and phosphoric acid are both good.

No. IX.—This sample is of dark bottom land of excellent texture. The sample is an excellent one when measured by the standards given before. The lime supply is very abundant as is also the potash and the phosphoric acid, and the humus is good. The high content of iron plus alumina might indicate that the phosphoric acid is not as available as in some others carrying a smaller per cent. of those elements. The soil is an excellent one for either fruit or general farming.

SOILS FROM JOSEPHINE COUNTY.

COMPONENTS.	No. 615. A. H. Carson, Grant's Pass.	No. 615½ Ditto.	No. 616. Harry Smith, Grant's Pass.	N. 67. A. H. Carson, Grant's Pass.	No. 622. Ditto.
Character of soil	Foot-hill	Subsoil	Bottom loam	Granite	Granite
Coarse material > .5 m.m	62 38	81 00	35 00	47 50	-------
Fine earth	37 62	19 00	65 00	52 50	-------
Moisture absorbed at 15° C	....	....	....	-------	-------
Capacity for water	-------	-------	-------	-------	-------
ANALYSIS OF FINE EARTH. [AIR DRY]					
Insoluble matter	68 20	68 56	60 93	81 56	90 20
Soluble silica	7 17	7 12	12 43	6 66	4 06
Potash (K_2O)	19	27	} 1 85	31	30
Soda (Na_2O)	07	12	}	38	87
Lime (CaO)	2 49	3 49	3 11	28	72
Magnesia (MgO)	46	43	3 36	35	33
Manganese (Mn_3O_4)	-------	-------	1 16	-------	-------
Iron (F_2O_3) } Alumina (Al_2O_3) }	11 47	11 54	11 97	5 17	2 45
Sulfuric acid (SO_3)	....	-------	Trace	05	-------
Phosphoric acid (P_2O_5)	21	23	06	05	-------
Water and organic matter	8 56	9 01	5 13	3 94	2 07
Total	98 82	100 77	100 00	98 75	101 87
Humus	2 44	-------	70	97	58

Josephine county does not possess as extensive an area of agricultural lands as most of the other counties, but such lands as do exist are of extreme fertility, and some of the most thrifty orchards of the State are located on her soils. The soils whose analyses are presented below are representative of her rich fields.

No. 615 is a typical red foot-hill soil sampled to a depth of 2 feet. This soil represents nearly one-half of the county. Its natural herbage is pine, fir, black oak, white oak, chaparral, manzanita, laurel, spruce and lilac. On wetting the soil darkens slightly, and becomes quite sticky on kneading. Orchards have been planted quite extensively on this soil and all do well when properly cultivated. The lime supply is very abundant, phosphorous is plentiful; potash is limited--the minimum would be allowable on account of the most excellent lime supply. The humus supply is also excellent.

No. 616 is a sample of the Rogue river bottom loams. It extends about one mile on each side of the river. It is a soil of excellent texture and is easily cultivated. Its natural growth is pine, oak, madrona and manzanita. As with most Southern Oregon soils the lime content is excellent; potash is plentiful; humus limited; and phosphoric acid weak. Phosphatic fertilizers would improve this soil even now.

No. 617—This sample is a typical granite soil from the vicinity of Grant's Pass. Soils of this type are said to compose about one-twelfth of the available lands of this locality. The soil consists almost wholly of decomposed granite. The native trees are pine, oak, madrona and fir, and the shrubs lilac, manzanita, and chaparral. These soils are somewhat subject to washing. Peaches are grown on these soils quite extensively. The soil is characterized by the following chemical conditions: lime supply, fair; potash supply, good; phosphoric acid, deficient; humus limited. Great care will have to be exercised to prevent these soils from early impoverishment. Such granitic soils are proverbially short-lived.

Jackson county comprises an area about 50 miles square. It includes nearly all of the Rogue river valley which is about 25 miles long by 5 to 25 miles wide. This valley is second in size to the Willamette valley. Her soils are subject to great local variations. The hill lands consist largely of volcanic matter, and decomposed granite, while the valleys consist of successive alluvial deposits of different geological periods.

No. 612 is a fair sample of the rolling lands. Its characteristic growth in oak and willow. The sample represents an area of about 6 x 20 miles. Fruit of all kinds has been found to do well on this soil and this would be expected from its chemical nature for its lime content is most excellent, its potash supply good—-inasmuchas it possesses abundance of lime—its phosphoric acid supply is good and its humus excellent. It is likely to be a very lasting soil. Its first need will probably be phosphoric acid.

SOILS FROM JACKSON COUNTY.

COMPONENTS.	No. 612. W. P. Olwell. Central Point.	No. 613. Ditto.
Character of soil	Black loam	Subsoil
Coarse material > .5 m.m	93 00	90 00
Fine material	7 00	10 00
Moisture absorbed at 15° C	-------	-------
Capacity for water	-------	-------
ANALYSIS OF FINE EARTH [AIR DRY].		
Insoluble matter	64 84	66 03
Soluble silica	5 57	8 33
Potash [K_2O]	33	21
Soda [Na_2O]	26	13
Lime [CaO]	2 32	5 15
Magnesia [MgO]	83	72
Manganese [Mn_3O_4]	Trace	Trace
Iron [Fe_2O_3] } Alumina [Al_2O_3] }	15 77	12 72
Sulfuric acid [SO_3]	-------	-------
Phosphoric acid [P_2O_5]	14	14
Water and organic matter	9 52	7 05
Total	100 58	100 54
Humus	3 55	11
Soluble phosphoric acid	-------	-------

THE COAST COUNTIES.

Under this division is included those counties which have a relatively large coast line. The counties included are Clatsop, Tillamook, Lincoln, Coos and Curry. In these counties the soils present somewhat different features and the climatic conditions are markedly different. This is particularly true of the precipitation, for whereas that of the Willamette valley is about 45 inches, in these counties it ranges from 58 to 75 inches.

SOILS FROM LINCOLN COUNTY.

COMPONENTS.	No. 1 A. C. J. Bishop, Tidewater.	No. 1 B. Ditto.	No. 1 M. G. H. Rosebrook, Toledo.	No. 1 N. B. M. Collins, Toledo.	No. 1 O. G. H. Rosebrook, Toledo.	No. 1 P. Ditto.	No. 1 Q. Ditto.	No. 1 S. Ditto.	No. 1 T. Ditto.	No. 1 U. Ditto.	No. 448. J. O. Stearns. Waldport.
Character of soil	Sandy loam	Ditto	Bottom	Ditto	Hill, low	Hill	Bottom	Bench	Tide land	Tide land	
Coarse material > .5 m m	2 00	1 01	3 40	7 40	7 40	16 31	20 00	....	00	2 90	1 50
Fine earth	98 00	98 99	96 60	92 60	92 60	83 69	80 00	....	100 00	97 10	98 50
Moisture absorbed at 15° C	5 00	10 00	4 99	70 86	70 09	11 74	6 94	5 00	2 55	9 95	....
Capacity for water	19 00	67 00	24 00	70 00	70 00	76 00	36 00	....	....	60 00	....
ANALYSIS OF FINE EARTH [AIR DRY].											
Insoluble matter	77 77	63 43	63 38	60 00	59 98	50 96	52 72	57 01	64 43	63 09	62 44
Soluble silica	4 94	8 60	8 15	9 40	9 74	9 52	14 54	11 43	7 44	6 37	3 87
Potash [K_2O]	1 76	10	12	19	29	38	33	16	22	33	11
Soda [Na_2O]	02	....	22	10	09	04	09	10	31	53	08
Lime [CaO]	23	1 40	53	43	31	30	27	42	45	27	46
Magnesia [MgO]	1 13	1 65	82	1 54	52	40	25	98	2 04	52	63
Manganese [Mn_3O_4]	27	09	06	08	08	10	20	.06	10	08	....
Iron [Fe_2O_3] / Alumina [Al_2O_3]	7 13	13 44	4 96	15 94	16 50	23 37	18 31	14 70	14 69	11 25	13 39
Sulfuric acid [SO_3]	....	....	02	03	02	04	03	01	02	01	33
Phosphoric acid [P_2O_5]	06	27	08	06	21	33	12	18	12	11	40
Water aud organic matter	8 16	10 62	12 00	12 53	12 15	14 17	12 90	14 60	10 32	18 07	18 99
Total	100 23	99 60	100 34	100 20	99 92	99 61	99 76	99 64	100 14	100 63	100 70
Humus	1 82	1 74	91	1 26	1 61	....	1 17	88	1 89	1 98	2 07

No. 1 A—This is a sample of original bottom land now covered by 1 B. The soil was sampled to a depth of 20 inches. Analysis shows it to be poor in lime, deficient in potash and to have a limited supply of phosphoric acid. Its humus supply is good. The soil is not a lasting one by any means, although its fine texture would have a tendency to offset its deficiencies for a time. It would be much improved by applications of gypsum.

1 B—This alluvium is about four feet deep and of a brownish color. As is shown by the mechanical analysis, the soil is of fine texture, the coarse material consists almost entirely of organic matter, sticks, etc. The soil shows a considerable portion of decomposed felspar. The lumps crush easily between the fingers. The natural growth of trees is cedar, red and yellow fir, alder, and maple; for shrubs and grasses, the vine maple, salmon berry, and native clovers. On account of depth and physical condition it seems to be an excellent soil for root crops, but the supply of potash is limited. It carries a high per cent. of lime, is strong in phosphoric acid, and is well supplied with humus.

1 M and 1 N—Except so far as the difference in chemical composition is concerned these soils are decribed as in 1 B. They carry less lime and phosphoric acid, which should be present in at least 10 per cent. to give the most satisfactory results. 1 N is also weak in potash. The color line in these soils is about 16 inches below the surface. The vegetation native to these soils is wild rye, wild pea, fir, maple, alder, spruce, salal and huckleberry.

1 O and 1 P—These run very closely together, 1 P however, being a little the heavier soil, and having, as would be expected, the greater moisture co-efficient. The supply of potash in each is fair and of phosphoric is good. 1 O is taken from the hillside verging on the bottom lands previously described, and shows no color line. 1 P is a sample of hill land above and represents thousands of acres, color line being at 10 inches.

1 Q and 1 S—The first is classed as a "bottom land" by the sender, but it is perhaps a first bench land as he says it lies higher than those previously given. Both are light soils quite well supplied with the critical elements, except humus, which deficiency could be remedied by the proper use of green manures. They are soils particularly adapted to truck gardening.

No. 448 is not a sample of an agricultural soil but was sent on account of its peculiar acidity which proved to be due to sulfate of alumina which was present in considerable quantity.

Coos county has a line of about 50 miles, and an area of about 800,000 acres, about one-half of which is heavily timbered with fir, cedar, spruce and hemlock. At present there are about 18,758 acres under cultivation, mostly along the streams tributary to Coos bay. There is also much tide land, or "slough bottom," which may be reclaimed by diking and draining. The soils are largely alluvial and well adapted to fruit culture.

SOILS FROM COOS COUNTY.

COMPONENTS.	No. 765. Anton Wirth. Marshfield.	No. 766. Ditto.
Character of soil	Red upland	Slough bottom
Coarse material > .5 m m	33 70	23 75
Fine earth	66 80	76 25
ANALYSIS OF FINE EARTH [AIR DRY].		
Insoluble matter	61 64	65 91
Soluble silica	4 71	4 28
Potash (K_2O)	20	29
Soda (Na_2O)	31	27
Lime (CaO)	52	41
Magnesia (MgO)	16	60
Manganese (Mn_3O_4)	15	06
Iron (Fe_2O_3) / Alumina (Al_2O_3)	22 24	17 24
Sulfuric acid (SO_3)	03	02
Phosphoric acid (P_2O_5)	11	38
Water and organic matter	10 48	10 85
Total	100 55	100 29
Humus	5 80	3 77

No. 765 is a sample of the red upland which characterizes, perhaps, nine-tenths of the county. The underlying rock is a sandstone, which contributes largely to the formation of the soil. Analysis shows the soil not to be strong in available plant food. The high iron-plus-alumina would indicate that the phosphates are relatively insoluble, and practice shows that the soil is rather short-lived. The report accompanying the sample says: "It does not produce good crops except where heavily manured." The native growth is alder, intermingled with Douglas spruce, cedar, myrtle, and vine maple. Oxalis and reeds are also abundant. The report states that, "Red clover grows luxuriantly.

I have seen a good stand for 8 years without reseeding. White clover and blue grass grow vigorously."

No. 766 is a sample of the slough bottoms previously mentioned. When drained these soils produce excellent crops of grass and vegetables. Mr. Anton Wirth writes "I have experimented on these soils with lime and muriate of potash, on a small scale, with astonishing results. It is certainly a valuable soil for cranberry culture.

SOILS OF EASTERN OREGON.

The appearance of the soils in Eastern Oregon is altogether different from that of the western part of the State. By far the larger part is of a gray, ashy appearance, darkening much on being wet. One coming from the darker soils of the Eastern States would be unfavorably impressed, but experience teaches that these soils are abundantly supplied with plant food, and analysis shows that they are probably the most fertile soils of the State. The wonderful fertility of these soils is shown in their enormous yield of crops from year to year. The soil is exceedingly deep in most localities, and of such a texture as to be easily worked. Speaking concerning the "dust soils" which cover so large a proportion of this eastern area of the northwest, it is stated in Bulletin No. 3 United States Weather Bureau, "*that the percentages of mineral plant food in these soils are quite large, and that according to all experience they should be found profusely and permanently productive. This forecast is abundantly confirmed by local experience.*"

Speaking of the soils of this same nature (silt or "dust" soils) a writer truly says: "The soil is indeed a wonder to all strangers, and it is difficult for them to believe at first that the land of such appearace as this is capable of raising anything, much less such wonderful crops as are really grown. In a part of the country, it is true, the soil when moist presents a dark, rich appearance, and this is really the best; but farther from the mountains, where it looks lighter and is loose and finer, it is scarcely less productive. In summer, when no rain has fallen for several weeks perhaps, it is so dry on the surface, so light and parched in appearance, that a stranger unacquainted with its qualities, would pronounce it utterly useless. But he need only wait till harvest for abundant proof of the maxim that 'appearances are deceptive.' One marked feature of this soil is its capacity to retain moisture, so that when after some weeks without rain the surface seems parched with drouth, the soil a few inches below will be damp, and grain will be found growing green and rank, and later, ripening into a bountiful harvest, when, under similar climatic conditions in many localities, any plants would have starved for lack of water."*

The physical nature of these soils is well shown by the following analysis:

MECHANICAL ANALYSIS OF FINE EARTH.

SOIL FROM MORROW COUNTY. †

Clay	1 27
Sediment of < .25 millimeters by hydraulic value	39 26
Sediment of < 25 to .5 millimeters	12 75
Sediment of < .50 to 2.0 millimeters	37 51
Sediment of < 2.0 to 8.0 millimeters	10 92
Sediment of < 8.0 to 64.0 millimeters	3 97
Total	98 75

While the soils of this eastern division of the State are mostly of the silt or dust character, yet there are certain areas of considerable extent which are materially different in nature. A notable exception is found in the Hood River locality, a portion of the State noted for its horticultural effects. While the soils of this region are entirely different from most of the others of Eastern Oregon—resembling more nearly those of Union county—the peculiar adaptability of the section to the growing of fruits, particularly apples, strawberries, and peaches is doubtless not as much due to its soil as its climatic conditions. Speaking concerning this latter point Mr. B. S. Pague of the Weather Bureau says: "On a strip of land extending along the Columbia from the Cascade Locks to about fifteen miles east of The Dalles, and southward from three to ten miles, can be found the highest or warmest night temperature from June 1st to September 1st of any place in Oregon. I venture to make the assertion that inside of the next ten years this section will produce the best peaches raised on the Pacific Coast; and, further, considering the area of this warm belt, more peach trees will be planted there than in any area of ground of equal size in the State."

* Resources of Oregon, 1892. † Bulletin 3 U. S. Weather Bureau. Hilgard.

SOILS FROM EASTERN OREGON.

COMPONENTS.	WASCO COUNTY.				UMATILLA COUNTY.		UNION CO.	BAKER COUNTY		CROOK CO	§ MORROW CO.
	No. 762. W. A. Slingerland, Hood River.	No. 763. H. L. Crappen, Hood River.	No. 764 M. V. Rand, Hood River.	No. 644. Amos Root, The Dalles.	No. 408. S. T. Lovell.	* Umatilla.	No. 1 Z. A. H. Todd, Meacham.	No. 406. Geo. Palmer, Baker City.	No. 407. T. Smith, Baker City.	‡ No. 1 Y. J. L. Linton, Cross Keys.	‡ Willow Creek.
Character of soil	Grey clay loam	Red clay loam	Red clay loam	Grey clay loam	Silt	Silt	Sandy	Silt	Silt	Sandy	Silt
Coarse material > .5 m m	35 44	42 93	37 10	25 50	00	--------	40	6 66	15 20	4 40	--------
Fine earth	64 56	57 07	62 90	74 50	100 00	--------	99 60	93 34	84 80	95 60	--------
Moisture absorbed at 15° C	--------	--------	--------	--------	--------	--------	4 70	--------	--------	3 85	--------
Capacity for water	--------	--------	--------	--------	49 00	--------	61 00	44 00	46 00	36 00	--------
ANALYSIS OF FINE EARTH [AIR DRY].											
Insoluble matter	68 15	62 42	51 03	63 65	69 66	84 58	65 75	60 29	68 49	76 69	79 21
Soluble silica	11 48	5 59	6 43	12 65	17 14	28	8 05	20 81	10 73	8 47	2 30
Potash [K_2O]	31	20	41	12	23	44	84	51	03	83	89
Soda [Na_2O]	71	67	73	16	49	1 19	23	26	02	20	05
Lime [CaO]	82	38	84	1 41	1 86	1 34	76	1 13	94	1 21	1 37
Magnesia [MgO]	15	24	24	1 10	09	70	24	1 93	01	1 11	1 08
Manganese [Mn_3O_4]	12	23	37	--------	40	--------	02	06	--------	04	06
Iron [Fe_2O_3] } Alumina [Al_2O_3] }	9 80	25 13	29 10	9 23	8 08	8 71	14 85	10 79	12 09	9 11	11 65
Sulfuric acid [SO_3]	Trace	01	07	--------	10	04	Trace	01	Trace	--------	03
Phosphoric acid [P_2O_5]	22	25	82	28	25	19	07	14	02	08	--------
Hydrochloric acid	--------	--------	--------	--------	--------	02	--------	--------	--------	--------	--------
Water and organic matter	6 42	6 67	12 52	11 81	1 70	2 57	8 09	4 82	7 50	3 35	2 55
Total	98 18	101 89	102 56	100 41	100 00	100 53	100 00	100 75	99 83	101 09	99 35
Humus	1 30	2 14	2 07	4 42	73	04	1 10	1 12	86	41	44

*Bulletin 10, U. S. Dept. of Agriculture. † Nitrogen. ‡ Does not include hydroscopic moisture. § Bulletin No. 3, U. S. Weather Bureau. Hilgard.

Nos. 763 and 764.—These samples are all of red soils of laval origin the color being due to oxid and phosphate of iron which are present in considerable quantities. Of these two soils 764 seems to be the stronger sample in mineral food and to equal its companion in organic matter. Both, however, are soils of first quality, very rich and of excellent physical texture. Phosphatic fertilizers will certainly not be needed on soils of this character for many years. In 764 lime is the weakest point but it could not be called deficient in a soil of the depth of this. It is not likely to be much benefited by fertilizers at present unless perhaps by an application of lime. No. 763 has a low potash content and might be benefited by applications of a mixture of lime and muriate of potash. It is not probable that this deficiency of potash is a characteristic feature of these soils. Much fruit has been planted on soil of this character and with most excellent results.

No. 762 is a sample of a soil of lighter color. There would appear to be no inherent reason for the report which accompanies the sample which says that general farming is "moderately poor." The soil analyzed has an abundance of potash and phosphoric acid, a fair supply of lime and a good humus content. As with the other soils of this region its lime supply is its weakest point, and good results are likely to follow applications of that material. It is regarded as a lasting soil.

No. 644 is very quite similar to No. 762 in its physical appearance. It was taken from near Mosier, 12 miles from The Dalles. Its natural production is oak, hazel and pine. Analysis shows the soil to be weak in potash, but rich in the other ingredients. Its humus content is exceptionally high. Its high lime per cent. will in a measure compensate for the deficiency in potash, but ultimately the use of that element will have to be resorted to.

Umatilla county is one of the largest of the State, but her soils are wonderfully uniform. The county contains about 2,073,600 acres. The eastern and southern portions of the county are rendered somewhat montainous by being traversed by the Blue mountains, but taken as a whole it is of a level and rolling surface. Along the northern edge of the county there is a strip of sandy land that demands irrigation before it would be adapted to agriculture, although even now it furnishes a good range for stock as it produces "early fine grass very nutritious." When irrigated it will produce enormous crops of cereals.

No. 448 is a fair type of these silt soils which represent such an area not only in this county but also in other sections of eastern Oregon. It will be noted that the mineral food in these soils is very high and is not likely in any of these soils, barring possibly a few local exceptions, to need supplementing with commercial plant food for many years. Care should be taken however, in the matter of conserving the humus for this is likely to become one of the weakest points in these soils. Attention should be given to green manuring, and to the use of *well rotted* barnyard manure. The soils should be kept covered with some green crop so far as possible in the summer, instead of the too common practice of a perfectly bare fallow which has been conclusively shown to be much more exhaustive to the soil than the growth of fallow crops.

Union county ranks among the first in the State in agricultural possibilities. The largest body of agricultural land is in the Grand Ronde valley which is one of the most productive spots in the United States. The valley contains about 300,000 acres of rich level alluvial soil carrying a considerable amount of sand. Indeed nearly the entire valley may be called a deep sandy loam of a slightly red color. Notwithstanding both climate and soil render this county particularly adapted to diversified crops yet to the present time the crops have been almost exclusively wheat.

No. 1 Z is not a fair type of the soils of this rich locality as it is from the mountain land. In this sample the lime, potash, and humus supply is good, but phosphoric acid poor. However the fineness of the soil associated with an excellent lime supply will much alleviate this difficulty.

Baker county cannot at present be called an agricultural one, although the Powder river valley contains considerable very valuable agricultural lands. This valley is about 16 miles wide by 20 miles long and is surrounded by high mountains. In most localities irrigation has to be practiced to insure good crops, but for this there is an ample water supply. More interest is being shown in this locality in agricultural matters and this country has a bright future dawning.

Nos. 406 and 407 are characteristic silt soils and it is strange to find soils so similar in appearance differing so much in composition. The former is well supplied with potash and the latter deficient; both are well supplied with lime; the former fair in phosphoric acid, and the latter deficient; each is well supplied with humus.

No. 1 Y.—This sample of soil from Crook county is one of most excellent texture. The soil is the light gray silt which darkens slightly on moistening. It is abundantly supplied with potash but phosphoric acid and humus are both low.

GENERAL DISCUSSION OF RESULTS.

As a basis for discussion, below will be found a table showing the average composition of the Willamette valley soils, made up from 42 analyses, and in parallel columns will be found the average composition of California soils, and of the humid region farther east. When studied in the light of the preceding principles of interpretation much information may be gleaned.

TABLE SHOWING AVERAGE COMPOSITION OF OREGON SOILS.

ANALYSIS OF FINE EARTH.	Willamette Valley.	Southern Oregon.	Eastern Oregon.	* Average for States. [Humid.]	* Average for California. [Arid.]
Insoluble matter	65 18	62 45	66 59	84 03	67 88
Soluble silica	5 02	8 74	13 12	4 21	8 96
Potash (K_2O)	23	34	43	22	94
Soda (Na_2O)	18	21	22	09	28
Lime (CaO)	83	3 22	1 22	11	1 08
Magnesia (MgO)	76	80	75	23	1 49
Manganese (Mn_3O_4)	08	25	10	13	06
Iron (F_2O_3) } Alumina (Al_2O_3) }	16 45	15 35	10 68	7 43	15 02
Sulfuric acid (SO_3)	03	01	04	05	05
Phosphoric acid (P_2O_5)	21	13	14	11	08
Water and organic matter	10 77	9 52	6 21	3 64	4 40
Total	99 77	100 02	99 51	100 19	100 05
Humus	1 63	2 25	1 44	†1 50	75

Turning attention at first to the lime content, we find it to be .83 per cent. Basing our judgment on the principles previously laid down, these valley soils could not be considered deficient in this ingredient. It is popularly supposed that the valley soils are deficient in this ingredient. On account of this widespread idea, and its great importance to agriculture, the matter demands a careful consideration. I am at a loss to understand the general

*"Relation of Soil to Climate. Hilgard. † From limited data.

acceptance of this idea, unless it be, *first*, that no considerable deposits of lime occur within this area, *second*, that the older text-books have placed the limits for a calcareous soil (4 to 20 per cent.) altogether too high as shown in more recent experiments, *third*, that poor results are often obtained with clover which is known to be a lime-using plant. However it may have sprung up *it is a fallacy*, at least so far as the bottom lands are concerned. Waiving the first possible cause of this notion as indicating nothing on the negative side of the lime question, as there are other compounds which may give rise to lime in soils, we come to the text-book statement concerning a calcareous soil. It is admitted that the soils are not *markedly* calcareous, yet "very much smaller percentages suffice to do all that lime can do: in very sandy soils less than two-tenths of one per cent. impart the calcareous character to vegetation; in very heavy clay soil, from one-half to three-fourths of one per cent. is necessary for the same purpose. But any further addition of lime to such soils changes the character of the vegetation no further, unless pushed to the extent of modifying materially its physical condition."* It is admitted as true that poor results with clover are often obtained, but that this is due rather to the present physical condition of the soil than to any inherent deficiency has been amply proven by results obtained at this Station, and also *by those farmers who have solved the problem of a proper physical condition for the crop. At the present time lack of drainage lies at the root of the difficulty with this and many other crops in the Willamette valley.* The soils of the Willamette valley seem to be moderately supplied with lime, but carry a much less amount than either the soils of Southern or Eastern Oregon, the former on account of geological reasons, and the latter on account of climatic conditions. That these soils should be fairly well supplied with lime would be expected from *a priori* reasons on account of the basaltic origin a large part of them. The lime in the valley soils is not altogether in the form of a carbonate, indeed it is rare that sufficient carbonate is present to cause evident effervescence with acid, but even a casual examination shows a very common oocurence of *easily decomposable zeolites*, *principally mesolite*, from which, by weathering, the lime may be constantly supplied. The general appearance of these zeolites is shown in the *frontispiece*. They

*"Soil Studies and Soil Maps," Hilgard in Overland Monthly.

occur in nodulary forms, silky fibrous and often interlaced; color, white to yellowish. The general composition of this mineral is:

Silica	45.6
Alumina	26.0
Lime	9.5
Soda	5.2
Water	13.7
Total	100.0

The decomposition of the amygdaloidal basalts *would naturally produce soils rich in lime and poor in potash.* Referring now to the minimum per cent. of potash for a strong clay loam we find it ought to carry at least .30 per cent. to be consistent with good productiveness and durability, but in referring to the average content of the valley soils we find but .23 per cent., an amount much smaller than could be desired. But this is as consonant with our premise that such soils are likely to be low in potash as is the high lime content. It is altogether probable, however, that the potash of these soils is of a high general availibility on account of the widespread disintegration of basaltic rocks and zeolites. It is a well known action of lime to render available potash compounds otherwise inert. Just here, methinks, is, in a measure at least, the explanation of the wonderful fertility of the Northwest soils, but long continued draughts on the side of potash, as will be made by fruit culture, is likely to rapidly deplete the soils of this ingredient. *In the light of the present indications it is altogether likely that when the valley soils "give out" it will be first on the side of potash.* and that in not a few instances could it be used to advantage now.

Analysis shows the phosphoric acid content to be about .21 per cent., which is all that could be desired, yes, even abundant. It is not at all likely that this will be demanded for many years to come, and this will be particularly true of the hill lands. *This heavy per cent. of phosphoric acid in our soils, together with the probably high general availability of what potash does exist, will go a long ways toward explaining the long continued productiveness of the Northwest soils, when sowed to grain. But when the conditions are so changed as to bring the draught very heavily on the side of potash, as will be done in fruit culture, if we may judge from the chemical nature of the soils, it is not at all probable that anything like these lasting qualities will be shown.*

†TABLE OF ANALYSES OF OREGON SOILS.

Number	Soil title	Name and locality	County	Coarse material > .5 m.m.	Fine earth	Moisture absorbed at 15 C.	Capacity for water	Insoluble matter	Soluble silica	Potash [K_2O]	Soda [Na_2O]	Lime [CaO]	Magnesia [MgO]	Manganese [Mn_3O_4]	Alumina [Al_2O_3] Iron [Fe_2O_3]	Sulfuric acid [SO_3]	Phosphoric acid [P_2O_5]	Water and organic matter	Total	Humus
1 A	Sandy loam	C. J. Bishop, Tidewater	Lincoln	2 00	98 00	5 00	19 00	77 77	4 94	1 03	02	23	1 13	27	7 13	0 00	06	8 66	100 23	1 82
1 B	Sandy loam	C. J. Bishop, Tidewater	Lincoln	1 01	98 99	10 00	67 00	63 43	8 60	10	......	1 40	1 65	09	13 44	0 00	27	10 62	99 60	1 74
1 C	Loam	Henry Buxton, Forest Grove	Washington	1 00	99 00	5 00	55 40	76 19	4 49	03	01	34	1 71	22	8 76	0 00	03	8 51	100 29	.....
1 D	Red clay	Henry Buxton, Forest Grove	Washington	3 00	97 00	1 42	8 00	75 06	3 76	16	00	63	1 18	21	7 58	05	32	11 63	100 58	20
1 E	Prairie	D. C. Bolton, The Dalles	Wasco	3 00	97 00	5 00	51 00	77 79	7 16	0 00	0 00	65	1 41	40	6 45	......	02	6 55	99 94	.....
1 F	Shot-land	Anson Powell, Gales Creek	Washington	51 94	48 06	3 30	50 80	65 89	5 62	12	06	75	7 13	0 38	17 50	......	......	9 81	100 79	1 87
1 G	Shot-land	Anson Powell, Gales Creek	Washington	34 00	66 00	6 50	40 80	67 40	5 18	28	05	1 35	90	40	17 67	0 82	34	7 98	100 07	1 76
1 H	Shot-land	Anson Powell, Gales Creek	Washington	19 00	81 00	4 72	50 00	67 99	3 22	26	07	76	71	......	18 13	08	34	8 74	100 30	.....
1 I	Adobe	College Farm, Corvallis	Benton	2 25	97 75	......	56 00	38 91	16 74	11	03	1 60	1 78	08	23 21	......	01	17 44	100 00	1 80
1 J	Clay	College Farm, Corvallis	Benton	1 75	98 25	3 94	44 20	72 70	5 93	47	24	1 60	1 03	10	9 23	03	05	8 00	99 38	7 64
1 K	Clay loam	A. W. Lucas, Monmouth	Polk	18	99 82	7 76	53 00	74 02	6 44	24	05	60	55	05	8 90	0 11	3 26	8 06	100 26	7 88
1 L	Shot-land	B. M. Collins, Fir	Washington	33 00	67 00	8 30	45 00	63 62	9 74	11	08	1 47	1 27	22	12 88	04	30	9 80	99 54	32
1 M	Bottom land	G. H. Rosebrook, Toledo	Lincoln	3 40	96 60	4 99	24 00	63 38	8 15	12	22	53	82	06	4 96	02	08	12 00	100 34	91
1 N	Bottom land	B. M. Collins, Fir	Washington	7 40	92 60	7 09	70 00	60 00	9 40	19	10	43	1 54	08	15 94	03	06	12 53	100 30	1 26
1 O	Hillside, near bottom	G. H. Rosebrook, Toledo	Lincoln	7 40	92 60	7 09	70 00	59 98	9 74	26	09	31	52	08	16 50	02	21	12 15	99 92	1 61
1 P	Hillside lands	G. H. Rosebrook, Toledo	Lincoln	16 31	83 69	11 74	76 00	50 96	9 52	38	04	30	40	10	23 37	04	33	14 17	99 61	.....
1 Q	Bottom land	G. H. Rosebrook, Toledo	Lincoln	20 00	80 00	6 94	36 00	52 72	14 54	33	09	27	25	20	18 31	03	12	12 90	99 76	1 17
1 S	Bench land	G. H. Rosebrook, Toledo	Lincoln	......	......	5 00	......	57 01	11 43	16	10	42	98	06	14 70	01	08	14 60	99 64	88
1 T	Tide land	G. H. Rosebrook, Toledo	Lincoln	......	......	2 55	......	64 43	7 44	22	31	45	2 04	10	14 69	02	12	10 32	100 14	1 89
1 U	Tide land	G. H. Rosebrook, Toledo	Lincoln	2 90	97 10	9 95	60 00	63 09	6 37	33	53	27	52	08	11 25	01	11	18 07	100 63	1 98
1 V	Sandy loam	J. G. Stevenson, Eugene	Lane	5 70	94 30	2 00	50 00	63 02	8 77	09	07	60	27	02	15 90	02	16	10 51	99 43	1 21
1 W	Black loam	John Withers, Lebanon	Linn	22 90	77 10	7 55	44 00	57 82	7 23	15	07	3 51	21	12	16 89	02	11	13 07	99 21	1 88
1 X	Sandy loam	J. D. Wilson, Yoncalla	Douglas	45 40	54 60	1 24	42 00	39 58	10 43	44	26	2 05	42	08	29 45	01	16	17 21	100 09	1 30
1 Y	Silt	J. D. Linton, Cross Keys	Crook	4 40	95 60	3 85	36 00	76 69	8 47	83	20	1 21	1 11	04	9 11	......	08	3 35	101 09	41
1 Z		A. H. Todd, Meacham	Union	40	99 60	4 70	61 00	65 75	8 95	81	23	76	24	02	14 85	trace	07	8 09	100 00	1 10
......	Beaverdam	Beaverton	Washington	......	......	......	......	73 40	......	18	52	1 49	26	......	7 20	28	23	10 95	99 86	.....
2 A	Beaverdam	J. Vorhees, Woodburn	Marion	9 17	90 83	......	51 53	21 88	94	66	75	97	09	09	15 11	trace	13	8 50	100 56	3 50
2 B	Subsoil [2 A]	J. Vorhees, Woodburn	Marion	35 63	64 36	......	50 00	......	9 40	04	03	10	91	05	12 20	......	28	7 60	100 37	.....
406		George Palmer, Baker City	Baker	6 66	93 34	......	44 00	60 29	20 81	51	26	1 13	1 93	06	10 79	01	14	4 82	100 75	1 12
407	Alkali	T. Smith, Baker City	Baker	15 20	84 80	......	46 00	68 49	10 73	03	02	94	01	......	12 09	trace	02	7 50	99 83	86
409	Red hill	J. H. Emmett, Eola	Polk	41 34	59 66	......	32 00	56 56	12 59	02	01	2 01	02	trace	25 22	trace	02	4 20	100 65	3 90
424	Subsoil below [409]	J. H. Emmett, Eola	Polk	40 57	59 43	5 68	40 00	35 20	15 35	39	03	75	87	04	30 84	......	47	15 08	100 61	1 18
425	Shot-land	J. H. Bamford, Gales Creek	Washington	47 20	52 80	......	40 00	75 00	5 16	02	03	82	85	50	9 81	trace	04	8 90	101 11	58
426	Red hill	F. R. Smith, Salem	Marion	28 88	71 12	......	42 00	68 48	4 38	47	33	40	96	none	14 78	......	63	10 19	99 72	52
447	Shot-land	J. C. Johnson, Scappoose	Columbia	25 50	74 50	......	36 00	75 96	4 00	29	39	59	80	none	12 27	04	31	5 28	99 93	55
448		J. O. Stearns, Waldport	Lincoln	1 50	98 50	......	......	62 44	3 87	11	08	46	63	......	13 39	33	40	18 99	100 70	2 07
449	Bottom land	J. H. Rinck, Buxton	Washington	5 16	94 84	......	38 00	73 36	3 33	11	08	50	......	......	13 46	06	25	8 45	100 10	1 95
2 N	Sandy loam	J. H. Rinck, Buxton	Washington	1 38	98 62	......	48 00	70 98	4 20	51	33	49	71	trace	12 07	05	54	10 58	100 40	3 40
623	Beaverdam	J. H. Rinck, Buxton	Washington	40 74	59 26	......	44 00	63 48	5 31	17	19	1 13	38	trace	14 08	15	12	9 38	100 00	2 95
624	Sandy loam	J. H. Rinck, Buxton	Washington	8 43	91 57	......	52 00	82 59	24	23	14	64	1 45	16	9 34	01	21	4 99	100 00	1 42
454	Adobe	H. C. Perkins, Lewellyn	Lane	32 79	67 21	......	46 00	52 68	6 85	19	09	65	46	23	18 56	04	13	20 12	100 00	5 59
625	Shot-land	Frank Butler, Falls City	Polk	45 30	54 70	......	44 00	71 80	7 97	47	20	56	79	none	2 71	trace	22	11 20	100 00	6 59
408	Silt	S. T. Lovell,	Umatilla	......	100 00	......	49 00	70 21	17 14	23	49	1 86	09	40	8 08	10	25	1 15	100 00	73
597	Clay loam	College Campus, Corvallis	Benton	5 60	94 40	......	60 00	76 65	9 25	33	08	89	80	15	8 08	02	25	3 56	99 96	.....
612	Black soil	W. P. Olwell, Central Point	Jackson	93 00	7 00	......	......	64 84	5 57	33	26	2 32	83	trace	15 77	......	14	9 52	100 58	3 55
613	White subsoil	W. P. Olwell, Central Point	Jackson	90 00	10 00	......	......	66 03	8 33	21	13	5 15	72	trace	12 72	......	14	7 05	100 54	11
615	Foothill land	A. H. Carson, Grants Pass	Josephine	62 38	37 62	......	......	68 20	7 17	19	07	2 49	46	......	11 47	......	21	8 56	98 82	2 44
615½	Subsoil from [615]	A. H. Carson, Grants Pass	Josephine	81 00	19 00	......	......	68 56	7 12	27	12	3 49	43	......	11 54	......	23	9 01	100 77	.....
643	Beaverdam	J. C. Standish, Halsey	Linn	50	99 50	......	......	64 25	6 45	39	63	55	71	trace	15 09	......	40	11 47	99 94	3 60
644	Sandy loam	Amos Root, The Dalles	Wasco	25 50	74 50	......	......	63 65	12 65	12	16	1 41	1 10	......	9 23	......	28	11 81	100 41	4 42
626	Prairie	G. W. Dimick, Hubbard	Marion	35 00	65 00	......	......	62 23	13 00	12	65	95	62	trace	12 32	......	29	10 29	100 57	5 42
622	White land	E. K. Shaw, Brooks	Marion	62 00	38 00	......	......	72 32	......	46	19	trace	05	trace	12 21	......	07	14 70	100 00	2 73
629	Shot-land	John Barrett, Portland	Multnomah	35 50	64 50	......	......	60 65	11 12	25	33	1 27	1 23	......	12 24	......	40	12 16	99 65	2 60
616	Bottom loam	Harry Smith, Grants Pass	Josephine	35 00	65 00	......	......	60 93	12 43	* 1 85	......	3 11	3 36	1 16	11 97	trace	06	5 13	100 00	70
618	Red land	J. M. Donnell, Wilbur	Douglas	60 00	40 00	......	......	78 32	8 14	* 1 27	......	13	08	......	9 62	02	28	2 74	100 00	3 28
762	White clay loam	W. A. Slingerland, Hood River	Wasco	35 44	64 56	......	......	68 15	11 48	31	71	82	15	12	9 80	trace	22	6 42	98 18	1 30
763	Red soil	H. L. Crappen, Hood River	Wasco	42 93	57 07	......	......	62 42	5 59	20	67	38	24	23	25 13	01	25	6 67	101 89	2 14
764	Red soil	M. V. Rand, Hood River	Wasco	37 10	62 90	......	......	51 03	6 43	41	73	84	24	37	29 10	07	82	12 52	102 56	2 07
765	Red upland	Anton Wirth, Marshfield	Coos	33 20	66 80	......	......	61 64	4 71	20	31	52	16	15	22 24	03	11	10 48	100 55	5 80
766	Slough bottom	Anton Wirth, Marshfield	Coos	23 75	76 25	......	......	65 91	4 78	29	27	41	60	06	17 24	02	38	10 85	100 29	3 77
410	White land [undrained]	College Campus, Corvallis	Benton	16 50	83 50	......	......	70 26	5 53	06	07	66	......	04	13 51	05	03	10 13	100 34	1 22
411	Red hill	Belfountain Prune Co., Monroe	Benton	......	......	......	......	65 74	4 94	21	40	46	05	01	12 56	02	34	14 82	99 55	5 96
628	Red hill	S. R. Burford, Salem	Marion	5 00	95 00	......	......	72 04	4 99	48	31	32	50	......	14 70	......	19	7 75	101 28	4 53
628½	Red hill	S. R. Burford, Salem	Marion	15 00	85 00	......	......	71 99	4 18	52	20	34	33	......	15 58	......	22	8 38	101 74	3 11
768	Grey clay loam	Geo. Thompson, McMinnville	Yamhill	3 00	97 00	......	......	74 02	2 45	26	54	63	63	trace	11 22	trace	23	11 25	101 23	3 57
769	Grey clay loam	Geo. Thompson, McMinnville	Yamhill	5 50	94 50	......	......	73 10	2 11	38	65	43	53	trace	10 01	trace	76	12 33	100 40	3 30
619	Red hill	Oregon Land Co., Salem	Marion	19 00	81 00	......	......	43 90	9 26	50	38	35	22	......	23 72	......	35	20 08	99 74	4 27
619½	Subsoil [619]	Oregon Land Co., Salem	Marion	......	......	......	......	52 33	......	62	......	......	28	......	24 84	......	30	23 12	101 49	3 16
617	Granite	A. H. Carson, Grants Pass	Josephine	46 00	54 00	......	......	81 56	6 66	31	38	28	35	......	5 17	05	05	3 94	98 75	97
622	Granite	A. H. Carson, Grants Pass	Josephine	......	......	......	......	90 20	4 06	30	87	72	33	......	2 45	trace	......	2 07	101 87	58
627	Prairie	G. W. Dimick, Hubbard	Marion	28 88	71 12	......	......	69 50	10 42	38	......	71	91	......	12 35	......	trace	4 06	98 33	76
	Average			24 54	74 33	5 65	46 79	65 08	7 69	32	29	97	8 24	16	12 68	0 70	26	10 05	100 21	2 42

* Potash and soda. † All analyses made to January 1, 1898.

The humus content of the soils—a fair measure of nitrogen—is excellent, 1.63 per cent., and largely exceeds that of California, .75 per cent., in whose soils the potash content is high. With proper care in the treatment of our soils it will be a long time before high-priced nitrogenous manures will have to be resorted to. It is not at all uncommon to find soils showing 2.5 per cent., and in rare cases even more.

I am now to speak briefly of the classes of soils, but limit it to those most prominent, for to undertake a consideration of the varieties due to local causes would demand much more data than is at our command.

In general in the bottom lands of the Willamette valley the soils have a tendency toward clay loams, with clay subsoils forming a hardpan at varying depths. There are apparently two classes of these soils, one a dark loam, and the other more properly described as a gray loam, running into the so-called "white lands." These are really of about the same chemical nature, and probably represent only different stages of drainage capacity, which has brought about subsequent difference in their composition. Even the so much despised "white land," when properly drained, rapidly takes on the appearance of the other soils both as to color and texture, the better drainage of the darker soils, excepting the adobe, allowing more perfect humification, and preventing the loss of much valuable plant food. *These loams are rich in phosphoric acid, and humus, well supplied with lime, but weak in potash.*

The class of soils known as "shot-lands" are worthy of special notice. These soils are of a reddish color and are quite lumpy. They do not blacken to any extent when wet but become very sticky. There is considerable iron oxide in the soil together with quartz and feldspar, with some hornblende. These soils are commonly called "shot-lands" since the iron oxid with particles of clay have formed small nodules which to some extent resemble shot, which by continued wear in cultivation disappear. This so-called "shot-land" covers quite an area of hill country embracing nearly all the lands on the first bench of the Coast Range lying on the south side of Gale's Creek, and also considerable areas in Multnomah, Clackamas and Columbia counties. As the bottom-lands are approached the shot become less. The natural growth on this soil is fir, alder, maple and an occasional oak. In many cases these soils are quite deep, sometimes 20 feet, but more often less than 10 feet. They are usually well drained and easily worked but wash quite badly in heavy rains. In general the water is soft and chalybeate springs are more or less abundant. Considering the depth and porosity of these soils none would be considered deficient in potash except No. 425, which for some cause appears to be *very* deficient both in this ingredient and in phosphoric acid, but fairly supplied with lime. I am of the opinion that applications of gypsum and organic matter would benefit any of these soils.

To summarize the matter of valley soils, the bottom lands offer, as a rule, the following advantages over the hill lands:

1st, Greater accessibility.

2d, Greater depth.

3d, Greater lime content.

4th, Probably a greater availability of potash.

As an offset the following advantages are offered by the hill soils:

1st, Better drainage, and therefore a more friable soil.

2d, Better supply of phosphoric acid.

In other respects there appears to be little to choose between them chemically.

The soils of Southern Oregon in general carry considerably more lime than do the soils of the Willamette valley—at least twice as much--the average so far stands 2.22 per cent. for the former against .83 per cent. for the latter. Such a condition we would expect to find from geological reasons, this section having been the area of fringing and barrier reef lime deposits in the early geological history of Oregon. The lime is most frequently present as a carbonate. It is safe to say that the soils are stronger than the Willamette valley soils, not only in lime, but also in potash, *but weaker in phosphoric acid. It is not likely that these soils will first wear out on the side of potash, but rather on the side of phosphoric acid.* In this respect they approach the California soils, as will be seen upon examination of the table given on page 46, although richer in phosphoric acid. The humus content of the soils of Southern Oregon thus far examined has been considerably higher than in the Willamette valley. We are not prepared to offer an explanation of this fact at present, although it may be due to the long continued wheat crops grown on the latter soils, and the open culture thus necessitated.

The red soils of the foot-hills of the southern area are likely, from their origin, to be quite variable in their composition, which will, perhaps, account for the ill-esteem they have acquired. Before orchards are placed on these soils there should be a very thorough investigation of their lasting qualities. *The granite soils are proverbially short-lived.* They usually carry a high per cent. of potash, but are sure to be very variable. While orchards are likely to do well on these soils for a time, they will not be found durable for fruit culture.

Comparing the soils of the arid with the humid areas along the lines of so-called critical elements, it will be noted that the two sections differ markedly in lime content—*the Eastern Oregon soils carrying much more lime than those of the humid or western area.* There is one feature that differs materially so far as observed, viz., that *there appears to be no great difference between the lime content of the uplands and the lowlands of the arid area.* This conforms with conditions pointed out by Prof. Hilgard, of California, *that all arid soils are naturally calcareous.** The converse of this, however, is by no means true, for there may be local causes which will very materially alter the conditions. We have an illustration of this in the southern area of the humid region, where the lime supply surpasses that of the arid area.

The potash supply of the Eastern Oregon soils is also superior to that of the humid area, standing .43 per cent. against .23 per cent. In view of this abundant supply *it is not at all likely that these soils will wear out on the side of potash.* The greater abundance of potash in these soils is augmented much by being in a very soluble form thus rendering it even more available than that in the soils of the Willamette valley. The phosphoric acid supply of the humid area, however, is superior being .21 per cent. against .14 per cent. for the Eastern Oregon soils. This is doubtless the weakest point in the soils of the arid area of the northwest.

The humus percentage is excellent, although, as might be expected from climatic reasons, not as high as in the Willamette valley, *but recent experiments indicate that the humus of the arid regions carries much more nitrogen than do those of humid areas in the ratio of 3 to 1.*† If in future experiments this proves to be

*Report of California Station, 1892—1893.
†California Station Report, 1892–93.

true in our State, as without doubt it will, it means that while the humus per cent. is lower the actual nitrogen content is higher in the Eastern Oregon soils than in those of the western area. Summarizing the lime, potash, and phosphoric acid of the three great areas we find it as follows:

	Willamette Valley.	Southern Oregon.	Eastern Oregon.
Lime [CaO]	.83	2.22	1.22
Potash [K_2O]	.23	.34	.43
Phosphoric acid [P_2O_5]	.21	.13	.14

The climate has much to do with these differences, although the abundance of lime in the southern area is mainly due to geological reasons as mentioned before. There is a difference of from 20 to 30 inches in the annual rainfall of the two sections. *This difference in rainfall and the lower level of the bottom water, or country drainage, explains the accumulation of lime, potash, and other soluble compounds in the soil of the eastern area.* In not a few instances have these accumulated to such an extent that the salts appear on the surface in the dry season as alkali. It is well to state here that the material composing alkali is no different than that being formed constantly everywhere, and that its appearance on the surface is simply due to the fact that the rainfall is insufficient to carry these soluble salts into the country drainage, but from year to year they are periodically washed into the soil to the depth of a few feet only to rise again with the evaporation of the water at the surface. Hence it is seen that the deeper the water penetrates—provided only it does not reach the country drainage—and the greater the evaporation, the more salts will there be brought to the surface to appear as alkali. The depth to which the water of precipitation penetrates in most cases is marked by the existence of a hardpan at varying depths. This hardpan has invariably been formed by the cementing action of the lime upon the diffused clay carried down by the storm water. These basins are always found underlying bad alkali spots and *before any permanent cure can be effected the impervious layer must be destroyed, otherwise whatever may be done will be but a mere makeshift.*

It is well known to those who live in regions where alkali prevails that there are two kinds, viz., the white and the black varieties. Of these the former is by far the least injurious on account of its comparative neutrality. The main ingredient of the white variety is sulfate of soda, which, not having the power to dissolve the organic matter of the soil, remains white. It is comparatively harmless, and unless it has accumulated in excessive amounts is easily managed. *The most permanent remedy will be underdraining the land with tile and then thoroughly washing out the salt.* This is the *best* as well as the most expensive means of removing the difficulty. There are other cheaper and less expensive remedies, such as digging open ditches lower than the level of the surface of the land to be treated, running these drains into the nearest natural outlet. Then by flooding these lands, not allowing the water to stand long enough to soak into the soil and thus carry with it the dissolved salts, most of the alkali that has collected on top can be removed. This treatment repeated a few times and followed by thorough and deep cultivation will be all that is required. In many cases, where the white salt has not accumulated in too great quantities, deep and thorough cultivation will be all that is needed. Such frequent and deep tillage keeps the ground in good tilth, and prevents the rapid surface evaporation. It also mixes the top, which is likely to be the strongest, with the soil lower down, and therefore dilutes the salt.

The black variety of alkali is far more difficult to deal with on account of its ability to dissolve the organic matter, *humus,* of the soil. In times of drought these spots are marked by a series of black rings left about the margins of the dried up pools. The active alkaline ingredient of these soils is sodium carbonate, commonly called sal soda, the corrosive action of which is well known to housekeepers. When water is available, chemical remedies, coupled with those given above, may be successfully employed. By means of gypsum applied at the rate of 2,000 pounds per acre, the black form will be changed to the white, which may then be given the above treatment. *Gypsum is the only practical antidote for black alkali.* It should be sowed broad-cast and well harrowed in.

Certain crops also have the power to remove a considerable amount of alkali from the soil if grown for several years in succession. Among these are beets, carrots, turnips, and any crop which will shade the ground thereby lessening the amount of surface evaporation.

These alkali soils are the very richest in the State, a number of the compounds composing the alkali being recognized as of direct value as fertilizers, as sulfate of potash, phosphate of soda, nitrate of soda, chlorid of soda, and carbonate of ammonia, which occur together with the sulfate of soda, and carbonate of soda mentioned above. Thus it will be seen that from the very nature of the case these soils are bound to be very lasting, and in many instances will well repay for the trouble required to recover them.

ERRATA.

Page 23, first line, read *Columbia* for *Clackamas*.

Page 23, under analysis of fine earth from Yamhill county, read Na_2O for Na_9O; also Mn_3O_4 for Mm_3O_4; also Fe_2O_3 for Ne_2O_3.

APPENDIX

Directions for Sampling Soils.

First.—As a rule take specimens only from spots that have not been cultivated and have not been changed from their original condition, and always from more than one spot, avoiding of course, road-sides, cattle-paths, squirrel holes, or the bases of trees.

Second.—Record carefully the normal vegetation, trees, herbs, grass, etc., of the average land; avoid spots of unusual growth.

Third.—From the selected spot pull up the plants growing on it, scrape off the surface lightly to remove any partly decayed vegetable matter. Dig a vertical hole at least twenty inches deep. On the sides of the hole observe very carefully at what depth the change of tint occurs, which marks the lower limit of the surface soil, and record the same. Take a half bushel of the earth above this limit, and on a paper break it up and thoroughly mix. With the mixed soil fill a bag of strong material—an ordinary shot bag is good. Place on top a folded label on which is written in *lead pencil* your name, the date, locality, and the general name of the sample.

In case the difference in character of a shallow soil and its subsoil should be unusually great, a separate sample of that surface soil should be taken, besides the one at a depth of six inches.

Specimens of "alkali" soils should be taken only toward the end of the dry season as at this time they contain the maximum amount of injurious ingredients. Samples of salts that may be on the ground should be done up in a separate paper and sent with the soil.

Fourth.—Whatever lies below the line of change in tint is the "subsoil." If the soil is very deep be sure not to take the subsoil sample above the line of change. It is desirable to know what constitutes the subsoil to a depth of three feet, as the question of drainage etc., depends upon the substratum. In ordinary cases, however, 10 or 12 inches of subsoil is sufficient for examination.

A specimen of any rock from which the soil is evidently formed should be sent in the bag with the "subsoil."

Fifth.—All peculiarities of the soil and subsoil, their conditions as to drainage, behavior in the dry and wet condition so far as observed or ascertainable by inquiry; the presence or absence of "iron spots," concretion, or "bog ore," or of "White gravel;" character of the soil water—every circumstance indeed, that can throw light upon the agricultural quality of the land should be carefully noted and recorded.

The information should cover all points of interest to the settler, and should be as concise as possible.

Wet soils should always be shipped in boxes.

Each soil sample is accompanied by the following blank properly filled out by the sender:

SOIL DESCRIPTION—CIRCULAR NUMBER III.

County...........Locality...........¼ of..........¼ Section..........Township ....Range.........Waters of.........Creek.........River......... .Near what town.........Depth taken...........Nature of underlying rock...........Does this rock or any other observed, contribute to the formation of this soil.........Water at what depth.........Nature of water........ ..Is "alkali" visible or known to exist............. What kind of trees.........What kind of grasses or plants...............What shrubs—sagebrush, or other herbaceous plants..............Give the general lay of the land; its relation to water courses, rolling uplands, hills, or mountains; whether steep or gentle slope........... State the extent of country similar to the sample... ....Popular designation of country and soil...........What other kinds of soil occur in the same general region...........Does the soil sampled gully or wash in wet weather; and the effect on the lowland...........Width of valleys—their surface level or sloping...........Has tree planting been tried to any extent and with what success:..........General fitness of the land for cultivation or grazing........... What is the present practice and production with the land...........What is your opinion as to the value of the land for fruit culture, and does it seem especially adapted to any particular varieties of fruit...........Has fruit been extensively planted on this kind of soil and and with what success...........What fertilizers, if any. are being used on such soil as the sample..........Is irrigation practised or not..........Is it practicable..........Miscellaneous.........

Please fill out the above blanks as accurately as possible.

I do hereby certify that the soil sample accompanying this sheet was taken in accordance with the instructions furnished me by the Oregon Experiment Station.

Date................ Signed................