Exercises and syllabus for Soils course. [between 1920 and 1950?]

Thwaites, F. T. (Fredrik Turville), 1883-1961
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Not corrected

U S Dept Ag.

Bur Soils. Bull 96, 1913

Soils of the U S,

Marbut, CF, Bennett, HH, Lapham J E, Lapham M H

Laboratory Check List ---- Soils I

Drawer
2 glazed papers
1 box matches
1 brush, camel's hair
1 crucible tongs
2 evaporating dishes, large
6 evaporating dishes, small
1 set fractional weights
1 graduated cylinder, 25 cc.
1 graduated cylinder, 100 cc.
1 pinch cock
6 rod glasses
1 ruler, 12 inch
1 spatula, steel
6 test tubes
1 towel
2 triangles, pipestem
2 watch glasses, 4 inch

Shelves
2 beakers, 400 cc.
2 beakers, 250 cc.
1 burner, Bunsen and tubing
1 dessicator
1 filter stand
2 flasks, Erlenmeyer, 300 cc.
1 wash bottle, complete, 500 cc.
2 funnels, 2½ inch
2 funnels, 4 inch
1 pipette, 10 cc,
1 pipette, 25 cc.
1 ringstand and 2 rings
1 wire gauze
1 Mohr burette

Name_ _

Class (Soph_ _ _
(Jun._ _ _
(Sen._ _ _
(Grad_ _ _

Desk No._ _ _ _ _ _ _

Section No. _ _ _ _

Class Adviser_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

Date_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _192___

Directions for checking out at beginning of semester.

1. See that the supply of apparatus in your locker checks with the above list. In case of error report to instructor and have your supply complete before signing above. Finally hand this signed list to the instructor.

Directions for checking in at end of semester.

1. With this list returned to you, check up your apparatus, replacing from the stock room all missing pieces.

2. All apparatus, which you have signed for at the stock room but which is not listed above, should be returned to the stock room and a return slip made out for it.

3. When the apparatus supply in your desk checks with the above list, ask instructor to check it over, then lock desk and give the key to instructor.

TABLES OF WEIGHTS AND MEASURES

LINEAL MEASURE

1 cm. = .3937 in.

1 m. = 39.37 in. = 1.0936 yds.

1 in. = 2.54 cm.

CUBIC MEASURE

1 cu. cm. = .061 cu. in.

1 liter = 1.0567 qt. liq.

1 dk. l. = 2.6417 gallons

1 qt. = .9463 liters

WEIGHTS

1 gram = .03527 ounces

1 kilogram = 2.2046 pounds

1 cu. ft. water = 62.42 pounds = 7.5 gallons

1 gallon water = 8-1/3 pounds = 231 cu. in.

Area of circle πR^2

Circ. of Circle $2 \pi R$

Area of cylinder $2 \pi R H$

Vol. of cylinder $\pi R^2 H$

Area of sphere $4 \pi R^2$ or πD^2

Centigrade degrees = .555 times (Fahrenheit° - 32)

Fahrenheit degrees = (1.8 times centigrade°) + 32

$\pi = 3.1416$

INSTRUCTIONS CONCERNING LABORATORY WORK IN SOILS.

ATTENDANCE:

Prompt attendance at the beginning of each laboratory period is imperative. Students will be expected to be in the laboratory and ready for work at the appointed time for the period to begin.

Whenever a practice is assigned the instructor may devote some time at the beginning of the laboratory period to explaining the purpose of the practice, and to calling attention to details that cannot be included in the outlines.

REPORTS:

Each practice must be written up promptly after it is completed.

All questions should be clearly and fully answered in the note book. Note books will be graded on accuracy of results of the experiments, the way in which the practice is written up, and neatness of work.

Laboratory reports are due within 7 days after completing the practice. Five points will be deducted for each day that a practice is overdue.

ARRANGEMENT OF CONTENTS OF REPORT

The Laboratory report presented for approval must be arranged in the following order.

1. Brief statement of the object of the practice.
2. Brief statement of method used.
3. Data neatly and logically tabulated)
4. Type calculation in full.) On the right hand side of book.
5. Maps and graphs or curves)
6. Conclusions, including answers to questions.

7. Synopsis of reference reading assignment other than text.

Note: Where only page reference is made, refer to "Lyon and Buckman."

Credit for the course will not be given until all required practices are satisfactorily performed, and the results written up in ink and accepted by the instructor. No practice will be considered complete unless all the questions are answered. If the work is unsatisfactory, the report will be returned to the student with the errors indicated, after which the work must be corrected or the experiment must be repeated as indicated, within one week.

Note books may not be taken from the laboratory without permission. All note books must be l eft with the instructor in charge when called for.

PLANT FOOD ELEMENTS REMOVED BY HARVESTED CROPS

(Pounds per acre per year)

CROPS	Yield per acre	Nitrogen (N)	Phosphorus (P)	Potassium(K)	Calcium (Ca)
Alfalfa hay	5 tons	(238)	23.6	185.0	185.0
Barley, grain	40 bu.	35.3	7.1	11.8	0.8
Barley, straw	1 ton	11.2	1.6	19.9	4.6
Barley, total crop		46.5	8.7	31.7	5.4
Beet, sugar (roots)	15 tons	78.0	10.5	79.5	8.0
Blue grass(Kentucky)	2 tons	53.2	9.4	70.0	12.0
Buckwheat, grain	30 bu.	21.8	5.5	7.3	0.3
Buckwheat, straw	3/4 ton	12.5	0.85	14.1	10.3
Buckwheat, total crop		34.3	6.35	21.4	10.6
Cabbage (heads)	15 tons	105.0	9.2	72.0	36.0
Clover hay, medium red	2 tons	(82.0)	6.8	54.0	61.6
Clover hay, alsike	2 tons	(80.0)	12.0	57.5	39.2
Clover hay, Japan	2 tons	(77.6)	18.0	68.8	40.5
Corn, grain	65 bu.	59.0	9.1	12.0	0.7
Corn, stover*	1¼ tons	33.0	6.8	40.0	12.2
Corn, cob	900 lbs.	3.0	0.3	4.0	0.1
Corn, total crop		95.0	16.2	56.0	13.0
Corn, (for silage)	12 tons	81.6	16.7	87.5	14.0
Cotton, lint	500 lbs.	1.5	0.3	2.5	0.6
Cotton, seed	1000 lbs.	31.5	5.7	9.5	1.8
Cotton, total crop		33.0	6.0	12.0	2.4
Flax, grain	15 bu.	30.4	5.5	6.6	2.0
Flax, straw	0.9 ton	20.6	1.5	15.6	9.3
Cowpeas hay	2 tons	(124.0)	16.4	137.0	36.0
Flax, total crop		51.0	7.0	22.2	11.3
Hemp (dry stalks)	3 tons	20.0	4.0	44.0	30.0
Millet hay (common)	3 tons	80.0	9.5	107.0	16.2
Oats, grain	50 bu.	31.7	5.6	7.4	1.1
Oats, straw	1¼ tons	14.5	2.4	31.1	7.5
Oats, total crop		46.2	8.0	38.5	8.6
Onion (bulbs only)	500 bu.	60.0	11.0	52.0	31.0
Peas, grain	20 bu.	44.0	4.5	10.1	2.0
Peas, straw	1½ tons	30.0	2.5	26.4	42.3
Peas, total crop		(74.0)	7.0	36.5	44.3
Peas, green, total crop	7.5 tons	(85)	7.2	35.0	55.0
Potatoes, Irish (tubers)	200 bu.	42.0	6.3	53.0	2.4
Potatoes, sweet (tubers)	200 bu.	35.0	5.0	51.0	......
Rye, grain	25 bu.	26.5	4.5	6.6	0.5
Rye, straw	1¼ tons	12.0	3.0	16.4	5.5
Rye, total crop		38.5	7.5	23.0	6.0
Soybeans, grain	20 bu.	70.0	7.1	24.6	2.2
Soybeans, straw	1 ton	35.0	5.4	32.7	31.3
Soybeans, total crop		(105)	12.5	57.3	33.5
Timothy hay	2 tons	39.0	5.4	45.0	10.0
Tobacco, leaves**	1500 lbs.	41.0	2.7	59.0	41.0
Tobacco, stalk	1250 lbs.	26.0	2.5	33.0	6.8
Tobacco, total crop		67.0	5.2	92.0	47.8
Turnips (roots only)	15 tons	60.0	13.0	72.0	15.0
Wheat, grain	30 bu.	35.6	6.8	7.9	0.7
Wheat, straw	1.6 tons	16.0	1.8	19.6	4.3
Wheat, total crop		51.6	8.6	27.5	5.0

*When corn is shocked in the field weathering causes a loss of elements, especially potassium, from the stalk and leaves.

**Leaves and stalk containing 30 per cent moisture.

Practice I

INTRODUCTORY EXAMINATION OF SOILS

The object of this practicum is to familiarize the student with the stock soils that are in use in the laboratory and to call attention to some of the factors that serve to differentiate these soils.

The following stock soils will be in use in the laboratory:

1. Sand (Plainfield)
2. Fine sand (Coloma)
3. Sandy loam (Miami)
4. Fine sandy loam (Miami)
5. Loam (Marathon)
6. Silt loam (Miami)
7. Silt loam (Carrington)
8. Clay loam (Clyde)
9. Clay (Superior)
10. Peat (Decomposed)
11. Peat (Raw)

Obtain from the soils stock room approximately 25 grams of each of the stock soils. Examine each soil in its dry state, noting the following characteristics:

1. Color.
2. Texture, relative amounts of various sized grains.
3. Structure; single grained, pulverulent, crumbly, cl oddy.

Moisten a small portion of the soils and note the "feel" by rubbing some of the soil between the thumb and finger.

1. Is it gritty, smooth, plastic?

Pinch soil out between thumb and finger to form a thin "ribbon". (If the soil contains a high percentage of very fine particles called clay, a "ribbon" can readily be formed) Usually the soil will break over the finger and fail to "ribbon" if it contains a low percentage of clay.

Place about 5 grams of the soils in beakers and add to each beaker 25 cc. of dilute HCL, stirring the soils with glass rods to break up lumps. Pour off the acid and wash by decantation with water. Transfer some of the washed material to cover glasses, and with the aid of a tripod magnifier, study the character of the large fragments of the stock soils. The fine fragments are really of greatest importance in relation to plant feeding and growth, but the large fragments are important physically and to a lesser degree chemically. The fine portion of each soil was lost by decantation through the process of washing. Note the relative amount of fine material in each stock soil. The composition and character of the fine fragments will be studied later.

1. How many kinds of minerals can you detect in each soil? Name them by color and shape.
2. Are all of the minerals of the same size in the same soil and in the series?
3. If the minerals are of different sizes, what does this fact indicate with reference to the rate of decomposition of rock and soil minerals?
4. What is the predominating color of the large grains in the coarse soils?

Moisten another small portion of the soils and spread it in a thin layer on cover glasses. With the aid of the tripod magnifier study the relation of water to soil grains.

1. Does the water fill the spaces between the soil grains or does it tend to form films around the soil grains? Of what importance is this relationship to plant growth?

2. What is the dark material that coats the soil grains? Is all of the dark material found in these soils in a finely divided

condition? What is the source of this dark colored material?

You will now see that soil is composed of two general classes of material, mineral and organic. This mineral and organic material makes up about 50 per cent by volume of a loam soil when in good condition for plant growth. The mineral portion, except in the case of peats and mucks, makes up from 85 to 99 per cent by weight of the dry substance of the soil. The organic matter, being present in relatively small amounts, is vital because of its influence physically, chemically, and biologically. Both mineral and organic constituents contribute to the nutrition of plants.

The other 50% by volume is pore space. In this pore space are found the soil air, and water containing salts in solution, and the soil organisms. The proportion of air and water varies from time to time in the same soil and in different soils. The relative proportion by volume of solid material and pore space in soils is influenced by inherent soil conditions and by cultural practices, factors that will be studied in succeeding practices.

Reference: Lyon and Buckman, Chapter 1.

Practice 2

THE COMPONENTS OF A SOIL

Soils are composed of a mixture of mineral matter and organic matter. The mineral matter is the residue from broken down rock, and the organic matter, the residue from the incomplete decay of plants and animals. The mineral matter exists in the soil in the form of soil grains, ranging in size from easily recognized bits of gravel or undecayed rock, to tiny clay particles less than .005 mm in diameter.

Soils vary as to the relative proportion of the different sizes of soil grains - or, scientifically speaking, we say that soils vary as to their texture.

In most soils these individual grains, especially the smaller soil grains, are found grouped together into little clusters, or soil crumbs. The soil mass, therefore, possesses an irregular structure that may be called a "crumb structure".

Although the two general groups of matter - (1) inorganic and (2) organic - exist in very intimate relationship in a normal soil, it is possible to learn much regarding the character of the groups and their functions by studying them separately and in a more or less pure condition.

INORGANIC CONSTITUENTS OF THE SOIL

Soil Minerals

A mineral may be defined as any inorganic substance occurring in nature which possesses a definite chemical composition; and which usually has a definite crystalline structure; and definite physical properties.

The soil is made up of the fragments of minerals rather than of bits of the original soil forming rocks. These minerals are of two kinds:-(1) those that persist from the original rocks; and (2) those that are formed by weathering during the processes of soil formation.

Find on your desk a set of minerals numbered and named. Study each specimen in order, using the following descriptive data-(After Buckman, Cornell)

Your knowledge of these minerals will be tested at the beginning of the next recitation period by a ten minutes written quiz on the soil relationships of these minerals; and at the beginning of the laboratory period by a set of unknowns. Study chapter 1 of the text book laboratory notes, questions, and lecture notes.

You will be held for formulae and reactions marked thus (*)

Work out the answers to the questions that follow the discussion of each mineral before proceeding to the next.

Tabulate your observations as follows:-

Mineral	Occurrence	Composition	Color	Hardness	Cleavage

1. Quartz -- *SiO_2 (The most abundant of all minerals in soil.)

While in a pure state quartz is colorless, its many impurities give it various tints such as rose, smoky, milky, etc. The crypto-crystalline varieties include chert, flint and agate. Quartz is very hard (does not scratch with knife) and has no cleavage, breaking with concoidal fracturs. It is quite insoluble in water. It is distinguished by its glass-like appearance, its hardness, its fracture and its resistance to acids. It occurs especially in granites and similar rocks and in sandstones.

1. Why does quartz decompose slowly?
2. What percentage of the earth's crust is quartz?
3. What percentage of the average soil is quartz?
4. Why does quartz (sand) make a soil friable?

2. Orthoclase - $*K_2O.Al_2O_3.6\ SiO_2$ (Source of potash in many soils)

Feldspars are silicates of aluminum forming a series ranging from potassium through sodium to calcium with many transitions especially in the plagioclases (see group 5). Orthoclase (microcline differs from it only in crystal form) is one of the most important of the group because of its potash content. Its color ranges from white through yellow and pinkish to red. The mineral can just be scratched with a knife. There is one distinct cleavage with a second less distinct one at right angles. The luster is usually pearly to vitreous.

In the presence of water and carbon dioxide orthoclase decomposes forming kaolinite (a clay mineral) and K_2CO_3. The latter is soluble and therefore available to plants.

$$*2\ KAl\ Si_3O_8 + CO_2 + 2\ H_2O = H_4Al_2Si_2O_9 + K_2CO_3 + 4\ SiO_2*$$

1. What percentage of the earth's crust is feldspar?
2. Give two reasons why orthoclase is important in soil formation?

3. Muscovite - $H_2KAl_3Si_3O_{12}$ with Mg and Fe
4. Biotite - $KHMgFe_3(AlFe)_2\ Si_3O_{12}$ (Both are sources of potash)

The micas are very complex aluminum silicates. The muscovite carries more potash and less iron and magnesium than the biotite. They are both very common in igneous rocks and in schists. Their flake-like character, their color, softness and luster make identification easy. In soils they are quite noticeable because of their glitter.

The micas are very important soil builders since they decompose into kaolinite (stained with iron) and soluble carbonates especially of potassium. A simplified reaction is as follows:-

$$2\ H_2KAl_3Si_3O_{12} + CO_2 + 4\ H_2O = 3\ H_4Al_2Si_2O_9 + K_2CO_3$$

1. Give two reasons why the micas are important in soil formation?
2. How do the two micas differ in appearance? Why?

5. Pl agioclase

The plagioclases are mixtures in varying proportions of sodium and calcium silicates. Albite and auorthite are taken as types

Albite $*Na_2O.Al_2O_3.6SiO_2$ very often occurs in rock interlaminated with orthoclase from which it is distinguished by its tabular crystals with fine striations on certain faces. The color is usually white to bluish gray. There is one perfect cleavage with another also at right angles less perfect.

Albite is as important in soil formation as either orthoclase or the lime plagioclase although sodium probably performs no such important function in plants as either potassium or calcium. It decomposes into kaolinite as illustrated under orthoclase.

Anorthite ($*CaO.Al_2O_3.2\ SiO_2$) decomposes as:-

$$*CaAl_2Si_2O_8 + CO_2 + 2\ H_2O = H_4Al_2Si_2O_9 + CaCO_3$$

1. Reaction for decomposition of albite?
2. Why is albite as important in soil formation as orthoclase?
3. In what two ways is anorthite important in soil formation?

6. Calcite - $*CaCO_3$
   Dolomite - $CaCO_3 . MgCO_3$

Calcite is a common rock mineral found especially in limestone and marble but also occurring in some igneous and metamorphic rocks. Upon changing to the bicarbonate the calcium is soluble and is lost from soils by leaching to a greater extent than any other element. (See text, page 210)

$$*CaCO_3 + CO_2 + H_2O = CaH_2\ (CO_3)_2*$$

In color calcite ranges from white to black, the luster is vitreous and the cleavage highly perfect giving characteristic rhombohedrons. The mineral can be cut easily with a knife. It effervesces readily with cold acids, which distinguishes it from dolomite. It is important for the calcium that it carries and in the form of ground limestone is added to the soil in large amounts to correct soil acidity.

Dolomite like calcite is often tinted. When granular either coarse or fine, it resembles marble. Dolomitic limestone may be used as agricultural lime and as such has a greater neutralizing power than calcite.

1. Calcite is treated with HCl. Reaction?
2. Why does dolomite have a greater neutralizing power than limestone?

7. Augite -
   Hornblende - Both yield clay minerals and soluble bases.

Augite and hornblende are chemically quite similar, the latter being often considered a double molecule of the former. They are calcium, magnesium, iron silicates of aluminum. Both occur especially in igneous rocks, while hornblende is prominent in metamorphic rocks as well.

Augite is generally greenish in color with only occasional distinct cleavage. Hornblende is generally black, often glossy and is distinguished by its columnal form. Many small cleavage faces at acute or obtuse angles are apparent.

Both of these minerals are important as soil builders, decomposing into kaolinite, serpentine, talc, chlorite and epidote and setting free such bases as calcium, magnesium, and iron. A simplified reaction is as follows:--

$$6\ Ca(Mg,Fe)Si_2O_6 + 9\ CO_2 + 2\ H_2O = 6\ CaCO_3 + 3\ FeCO_3 + H_4Mg_3Si_2O_9 + 10\ SiO_2$$

(Augite) (Serpentine)

1. What is likely to be color of a residual soil from rocks containing augite or hornblende?
2. What nutrient elements are carried by augite and hornblende?

8. Olivine - $(Mg,Fe)_2SiO_4$

Olivine is found commonly in basic igneous rocks and is rather unimportant in forming soils. It is present very sparingly in soils. Its olive-green color, hardness and granular character are sufficient for its identification. It alters readily to serpentine and iron oxide. The serpentine later yields magnesium carbonate (see group 11) and the FeO changes to red Fe_2O_3 (See group

$$3\ MgFeSiO_4 + 2\ H_2O = \underset{\text{Serpentine}}{H_4Mg_3Si_2O_9} + SiO_2 + 3\ FeO$$

1. Why is olivine of secondary importance in soil formation?
2. Why is it seldom found in soil?

9. Apatite - $*3\ Ca_3(PO_4)_2 + Ca(Cl,F)$ Source of phosphorus.

Apatite exists in many rocks although in small amounts. The color is generally brown although greens and whites occur. In decomposing little phosphorus is lost due to the absorptive power of the soil. Soils therefore often contain more phosphoric acid than the original rock (See analysis page 33). Apatite is the original source of all soil phosphoric acid.

1. In what other forms may phosphorus occur in soils? (See page 11).
2. Write the reaction showing how tri-calcium phosphate becomes available. (See page 455).

The nine groups studied above are important rock minerals and persist to a greater or less degree in the soil. The six groups following arise to a great extent through the weathering of the minerals just considered and are largely secondary in character. They are important constituents of the clayey portion of the soil.

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10. Kaolinite - $*H_2Al_2(SiO_4)_2.H_2O$

Kaolinite is a decomposition product of other minerals, particularly orthoclase (which see). In the soil it of course contains many impurities, especially absorbed materials which may be plant nutrients (as potassium, calcium, and phosphorus). Its soft earthy unctuous feel is characteristic. It belongs with the many indefinite hydrated aluminum silicates, called the clay minerals, which occur in soils, formed by the decay of the various original silicates.

A secondary mica called se ricite is quite often present in clayey soils. It arises from the decomposition of the feldspars and with kaolinite, chloriet, epidote, serpentine and talc makes up what is called the clay group of minerals. It is difficult to distinguish sericite from kaolinite.

$$3\ KalSi_3O_8 + CO_2 + H_2O = KH_2Al_3Si_3O_{12} + K_2CO_3 + 6\ SiO_2$$

Orthoclase Sericite

11. Serpentine - $H_4(Mg,Fe)_3Si_2O_9$
    Talc - $H_2Mg_3Si_4O_{12}$

These minerals are similar in chemical composition and character. They break down into highly magnesian clays stained with iron as follows:

$$H_4Mg_3Si_2O_9 + 3\ CO_2 = 3\ MgCO_3 + 2\ SiO_2 + 2\ H_2O$$

Serpentine is usually massive and of a dull greenish color. It is readily cut with a knife. The talc is generally white and greasy in feel. It is quite soft, often flexible and has a pearly luster.

12. Chlorite - Type Prochlorite. Hydrated Mg,Fe aluminum silicates

A considerable number of minerals are grouped under this name of which prochlorite is used as a type. These minerals are generally greenish because of ferrous iron. The chlorites resemble the micas but are much more highly hydrated.

The chlorites are usually secondary minerals arising in the soil through weathering of hornblende, augite, mica and similar minerals. With kaolin, sericite, serpentine, talc epidote and other indefinite materials they make up the clay mineral group, giving to soils high absorption and the sticky plastic character so well known in clay.

13. Epidote - Ca,Fe aluminum silicate.

This mineral often has a peculiar yellowish green although many other colors occur. The prismatic crystals are usually longitudinally striated.

Epidote arises through metamorphism and usually occurs in the soil from the weathering of such minerals as augite, hornblende and mica. In the soil it is finely divided and mixed with kaolin, chlorite and sericite helps to make up the clay mineral group.

1. List the common clay-mineral group.
2. What are the important characteristics of the group?

14. Hematite - $*Fe_2O_3*$

Hematite is only in certain cases an original mineral of soil forming rocks. It is a heavy metallic oxide arising from the weathering of any mineral carrying iron. Generally the iron staining of such a mineral is the first indication of weathering. The process is one of oxidation, the ferrous oxide appearing first (see olivine). This is further oxidized:--

$$*4\ FeO + O_2 = 2\ Fe_2O_3*$$

Hematite may be dark and compact or red and unctuous. Its streak is cherry or reddish brown. When finely divided as in soil it imparts a bright red color. (See page 36 of text book)

15. Limonite - $*2Fe_2O_3.3H_2O*$

Limonite (and similar hydrous oxides) is formed readily from hematite especially in soil.

$$*2Fe_2O_3 + 3\ H_2O = 2\ Fe_2O_3.3H_2O$$

Limonite may be concretionary, massive or earthy. It varies in color from brown to yellow. When finely divided as in soils it is generally distinctly yellow. It is distinguished from hematite by its yellow streak. Limonite stands as a representative of a great number of indefinite hydrous iron oxides that may occur in soils (see page 37). The admixture of these with hematite and organic matter give the various shades of reds, yellows, and browns so characteristic of many residual soils.

Both hematite and limonite occur in intimate mixture with the clay minerals.

1. What is the usual significance of the red color of a soil?
2. Where in the U. S. are red and yelloww soils most typically found? (See top of page 42)
3. [illegible]

Exercise 3

COMMON SOIL FORMING ROCKS

A rock is a considerable mass of one or more minerals. Sometimes one mineral may form almost the entire rock. Rocks may be classified according to their origin, texture and structure. From the soils point of view we are even more interested in another kind of classification, a chemical classification, based upon the relative proportion of SiO_2 that the rock may contain. Rocks high in total silica are said to be acidic, while rocks in which the metallic oxides predominate are said to be basic. An intermediate group lies between these two extremes. The physical and chemical make-up of the rock from which our soils are formed, determine quite largely their chemical and physical properties. On the basis of origin we have three important classes of rocks.

1. Igneous rocks: Rocks which have been brought up from below in a molten condition and which owe their present structural peculiarities to variations in conditions of solidification and composition (Merrill)

2. Sedimentary rocks: Rocks which are formed largely through the agency of water, being deposited in beds. The term "aqueous rocks" is more inclusive, since we always include under sedimentary rocks those rocks which have arisen as chemical precipitates.

3. Metamorphic rocks: Rocks changed from their original condition through pressure, heat, or solution and precipitation.

Examine carefully the specimens provided; determine their class, texture and color. Name distinguishable minerals. Arrange data in tabular form. Use following terms in describing class and texture.

Class: Igneous, Sedimentary, Metamorphic.

Texture of Igneous Rocks:

Grained - coarse, medium, fine
Dense
Glassy
Porphyritic

Texture of Sedimentary Rocks:

Grained - coarse, medium, fine.
Dense

Texture of Metamorphic Rocks:

Grained - medium, fine.
Dense
Foliated structure

An igneous rock is named according to its predominant minerals and its texture. Thus a rock that is made up largely of quartz and orthoclase and has a grained texture is called a granite. The name of a prominent accessory mineral is often added as, biotite-granite, hornblende gabbro, etc. Porphyritic specimens (crystals set in a fine ground mass) often occur marking one type of transition between the grained and stony textures.

Granite (After Buckman, Cornell)

Granites are granular rocks composed largely of feldspar (orthoclase and soda-lime) and quartz. Generally, more or less mica or hornblende is present. The quartz is generally observed as formless grains of a greasy luster. The general color of the rock depends upon the proportion of feldspar and the accessory minerals. The color thus shades from white into gray or dark gray resulting from the mottling of the mica. The rock is spoken of as acid due to the free SiO_2. It usually carries some apatite.

As a granite weathers it alters markedly. The mica bleaches, the ferrous compounds washing out and oxidizing to the ferric, staining the rock red. The feldspars hydrate and carbonate, giving up soluble constituents. The firm texture is lost and the rock crumbles down to a mass of sandy clay stained red from the rion compound present. The soil is likely to be acid and need lime. It carries considerable potash and phosphorus.

Gabbro

Gabbros are granitic igneous rocks composed of pyroxene and feldspar (usually soda-lime). Mica, olivine and hornblende often occur as accessory minerals. The rock is usually black or greenish black. It is classed as a basic rock.

Gabbros give rise by weathering to heavy clay soils stained brown or red with iron and often mingled with fragments of the undecomposed rock materials. Such soils are likely to be low in potash and phosphorus but high in iron and magnesium. The calcium is likely to be lost by leaching. The soil is usually benefitted by an application of lime especially if of residual origin.

Basalt

These rocks are dense, very dark and of fine texture. The color varies from grayish or greenish black to pure black, with often a velvety appearance. Basalt is generally composed of plagioclase feldspar and pyroxene (augite) with iron ore, and often olivine. It is frequently porphyritic.

Upon weathering the basalts soften to a brownish or greenish mass with the formation of chlorite, serpentine and carbonates. The iron tends to oxidize and a ferrugineous clay is produced high in iron and alumina but low in potash and phosphorus. The reaction of the soil is generally acid.

SEDIMENTARY ROCKS.

Sedimentary rocks consist of materials, which have already been a part of preexisting rocks, and which have been shifted from their former position. In general, they consist of layers and have little verticle extension. The texture depends upon the size of the particles and the kind and amount of the cement. All degrees of firmness are encountered. The color is variable. Quartz, feldspar, kaolin, mica, calcite, limonite and hematite are the minerals commonly found in such rock

Limestone and Dolomite

Limestone is one of our commonest rocks. It is usually fine grained, dense and variable in color. It effervesces with dilute acid and scratches easily with a knife. It is usually impure, containing quartz, clay, iron, phosphorus, etc. With increasing amounts of magnesium it grades into dolomite, which has the same general appearance as the lime stone. The dolomite is somewhat harder and will effervesce with cold dilute acid only on scratching.

In weathering the calcium and magnesium are removed in the bicarbonate form leaving behind the impurities, which form the soil.

$$\text{Impure } CaCO_3 + CO_2 + H_2O = CaH_2(CO_3)_2 + \text{Impurities.}$$

The residual soils formed therefrom are clays or loams, usually colored red or yellow by iron. Chert and masses of limonite are common. The soils thus formed are usually acid. Limestone soils formed by glaciation are of course rich in lime.

Sandstone

Typical sandstone consists of quartz cemented together. Other cemented minerals may occur as feldspar, mica, garnet, etc. The cementing material may be quartz, calcite, iron (hematite or limonite) or even clay. The colors vary from gray through buff, yellow, red and brown to white. The fracture is usually along the cement. The texture may vary from coarse to fine.

Sandstone in weathering usually gives way first along the cement, crumbling down to a mass of sandy debris which gives rise to sand or sandy loam soils. Such soils are generally low in all of the plant food constituents, and are apt to be acid. The rate of weathering, of course depends largely on the cement.

Shales

Shales are compact clays and muds often thinly laminated parallel to the bedding. They are generally so fine grained that the individual particles can not be seen with the naked eye. The minerals are mostly kaolins with related substances. The color ranges from white, through red, yellow, gray and blue to black. Shales are soft and cut readily with a knife. With an increase of sand, shales grade into sandstone while the presence of lime marks a change toward the limestones. Arenaceous, calcareous and bitumenous shales are common. All graduations between clays and shales are found.

Shales weather into shaly loams which are usually low in plant food constituents and consequently are rather unproductive. They generally are benefited by lime.

Conglomerates and Breccias.

Conglomerates are formed by pebbles of various sizes cemented together by finer material. Many kinds of minerals and rocks may be represented although quartz and feldspar are most common. The cementing material may be consolidated sand, calcareous materials or clay mixed with iron oxide. Often the cement is a mixture of all three. When the cemented fragments are angular the rock is called a breccia.

Conglomerates are generally formed by swiftly moving water. When they weather into soil, the cement first gives away, yielding coarse open debris which is of but little agricultural value.

METAMORPHIC ROCKS

When igneous or sedimentary rocks have been so changed as to texture or mineral composition or both as to have entirely new characteristics they are called metamorphic. As might be expected no definite line can be drawn since all graduations e xist. The agencies involved are heat, chemical action of gases and liquids and the movements of the earth's crust. Weathering with the formation of soil is really a phase of metamorphism.

Gneiss

Gneiss in a limited way refers to a rock with the same composition as granite but with a foliated texture. In a broader sense the term refers to any banded metamorphic rock composed largely of feldspar. The specimens used here are granite-gneisses. The banding is often difficult to see on hand specimens. The color passes from white through shades of gray or red to browns and blacks. The varities are named according to texture or from the presence of some mineral as banded gneiss, hornblende gneiss, etc.

Gneisses are very common rocks and have had to do with the making of large areas of soils. They weather much as do granites but less rapidly, yielding a red sandy clay, with a fair amount of plant nutrients. They are generally acid in reaction.

Schists.

The characteristic minerals of schists are mica and quartz, the former giving the rock its peculiar character, called schistosity. Many other minerals also are carried as hornblende, garnet, epidote, etc. The chemical composition of such rock is extremely variable. The color ranges from very light through yellow, brown and gray to black. Schists grade into gneisses on the one hand and into micaeous slates on the other.

Such rocks produce micaeous sandy loams with a low amount of available plant food although the potash content of such debris may be high. In general, they yield much poorer soils than granites and gneisses. The feldspar of the latter are an important feature.

Quartzite

Quartzite is a very hard and compact rock formed usually from sil icious sandstone. The change is so complete that the rock will break across the original sand grains. Accessory minerals such as mica, fel spar, epidote, etc. often occur. The normal color of the rock is ligh gray or brown although other colors may occur. The chemical compositi of typical quartzite is almost pure silica.

This rock resists erosion and weathering so well that it offers little toward a soil covering. Where it is present it usually forms the prominent landscape features.

Slate

Slates like shale are fine in texture. They are denser and hard however, and split readily into sheets. A variety of minerals are pre ent such as mica, quartz, chlorite, etc. The color is chiefly gray or black although reds, greens, yellows and browns occur.

Slates weather less readily than shales and afford a soil even less valuable from the agricultural standpoint. Slaty loams are the common type.

Marble

Marble is formed from limestone and dolomite by metamorphic agencies. Calcite is the essential constituent. The rock is seldom pure and may carry mica, amphibole, phyroxene, apatite, garnet, clay, etc.

Pure marble is white but many other colors occur such as pink, greenish, gray, etc., due to iron oxides, micaeous minerals or carbonaceous materials respectively.

Marble weathers in the same way as limestone but much slower due to its texture. The carbonates are removed as bicarbonates, the more stable impurities making up the soil. Marble soils are of small extent and unimportant.

1. Why is a gabbro less desirable than a granite in soil formation?

2. Why the difference in lime content between glacial and residual so

3. When a residual soil is formed from limestone what makes up the soil?

4. A granite carrying quartz, hornblende, orthoclase and albite weathers to a red gritty clay soil with a mottled yellowish sub-soil. Account for the characteristics of the soil.

5. What plant nutrients are present in quartz, orthoclase, mica, apatite and hematite, respectively?

6. A limestone carries 2% impurities, which in residual weathering form the soil. How many feet of limestone, approximately, must be dissolved to give ten feet of soil?

Exercise 4

ROCK WEATHERING AND SOIL FORMATION

-A-

CHEMICAL EFFECTS OF WATER AND CARBON DIOXIDE UPON ROCK-FORMING MINERALS

1. Add 100 c.c. of distilled water to a 300 c.c. Erlenmeyer flask. Boil down to a volume of about 50 c.c. Add 4 drops of phenolphthalein solution. Do you note any appearance of a pink color? Add 1/2 gram of a powdered silicate mineral such as anorthite ($Ca\ Al_2\ Si_2\ O_8$). Boil. Note any change in color of the solution. Write an equation which will explain the phenomena observed.

2. Add 10 c.c of $Ca(OH)_2$ solution and 10 c.c. of distilled water to a test-tube. Bubble CO_2 gas through the solution for 1/2 minute. What happens? Continue to bubble CO_2 gas through the mixture. What happens? Write equations which will explain the phenomena observed.

EFFECTS OF WEATHERING UPON IGNEOUS AND SEDIMENTARY ROCKS.

In order to make the processes of soil formation clearer, a brief study will be made of the formation of two residual soils. The specimens used in this exercise are samples taken from vertical sections. The following stages are represented.

1. Residual soil.
2. Very rotten rock.
3. Partly decomposed rock.
4. Undecomposed rock.

Make observations as directed and answer questions in order. Make use of following references.

Lyon and Buckman - "The Nature and Properties of Soils." Chapter II
Merrill - Rocks, Rock-Weathering, and Soils.

<u>Weathering of a Granite</u>.

Examine the fresh rock:-

1. List the minerals which you can identify.

2. What is the condition of the minerals?

Examine the disintegrated material (soil material) and answer the following questions (Adapted partly from Buckman)

1. What minerals of the fresh rock are still present?

2. To what has the orthoclase changed? Write reaction.

3. To what is the red and yellow colors due?

4. What four chemical changes have been active? Give illustration.

5. Define hydrolysis, and kaolinization.

Correlate the changes observed with the statements in the paragraph at bottom of page 29 of the text.

Place a spoonful of the residual soil in a beaker, and rub up with 100 c.c. distilled water. Stir, and let stand 1 minute. Decant off the supernatant muddy water. Repeat until the supernatant water is nearly clear. Now boil the residue in the beaker with 50 c.c. of dilute HCL. (Under hood) Pour off the HCL solution, wash by decantation with water. Describe and identify any minerals observed in the residue. What minerals predomin ate?

Weathering of Sedimentary Rocks

1. What is the principal mineral in the fresh rock? What test proves its presence? Identify other minerals. Name the rock.

2. Apply the same test to each of the other specimens in the limestone series. What do you conclude?

3. Describe and explain the color changes noted in the transition from rock to soil material.

Treat a spoonful of the residual soil the same way as the granitic residual soil. Describe and identify any minerals observed in the residue. What mineral predominates?

Obtain from the instructor a sample of the fine portion of each residual soil. Examine this material by feel and by handlens. What group of soil minerals does this material represent?

You now have before you two portions of each of the two soils divided roughly according to texture.

1. What minerals predominate in each part?

2, In what portion of the soil will the more SiO_2 be found? Potassium? Phosphorus? Why in each case?

3. How about the comparative amounts of mineral nutrients in sandy and clayey soils respectively?

4. What is the difference between soil material and soil?

--Analyses on Page 33 of Text--

5. What element practically disappears in both cases during weathering?

6. What is the practical significance of this loss?

7. In what forms is this element lost? See page 306, last par.

8. Why is there a larger percentage of P_2O_5 in the soils than in their respective parent rocks?

9. There is a larger percentage of K_2O in the limestone soil than in the parent rock. Why is this not true of the granite soil?

Note:- At the beginning of the next period you will be held for a 10 minute written quiz on the laboratory work on soil formation and on Chapter II of the text book.

-B-

LOSSES IN THE WEATHERING OF LIMESTONE

The object of this practice is (1) to familiarize the student in the construction and use of a simple piece of apparatus by means of which the carbonate content of limestone can be determined, and (2) to impress upon him that the value of limestone for agricultural purposes rapidly diminishes as the rock deteriorates in the formation of a soil.

Each student will construct a Kentucky calcimeter. The materials needed are one 4 oz. wide mouth bottle fitted with a one-hold rubber stopper, one 12 oz. wide mouth bottle fitted with a two-hole rubber stopper, one graduated cylinder, one 400 cc. beaker, a 1/2 oz. vial, 1 foot of rubber tubing, and glass tubing as shown in the sketch on the black board.

Place 1 gram of pure $CaCO_3$ in bottle A. Place the small vial in bottle A, after filling it about 2/3 full with strong HCL. Fill bottle B with water, and insert stopper tightly. Now blow through the free end of the rubber tube, and while the water is still running from the end of the delivery tube, connect the rubber tube with A. Let the water run into a beaker. When the water has ceased dropping, empty the water from the beaker and replace it under the delivery tube. Now incline bottle A so that some of the acid will spill onto the $CaCO_3$. The evolution of the CO_2 displaces the water in bottle B into the beaker. Add acid until all of the $CaCO_3$ is dissolved. Determine the volume of the water displaced. This volume is equivalent to 100% $CaCO_3$ provided the remainder of the practice is conducted under the same temperature and pressure conditions.

To analyze an unknown limestone, place a 1 gm. sample in bottle A, and proceed as directed above. The volume of the water displaced by the unknown divided by the volume of water displaced by 1 gm. of the pure $CaCO_3$ multiplied by 100, equals the per cent of $CaCO_3$ equivalent in the unknown.

Each student will determine the per cent of $CaCO_3$ equivalent in samples 1, 2, 3, and 4. Use a 10 gm. sample for the residual soil and a 2 gm. sample for the very rotten limestone.

Tabulate your data as shown.

Material	Cubic centimeters water displaced by sample used	Cubic Centimeters water displaced by 1 gm.	Per cent $CaCO_3$ Equivalent
Pure $CaCO_3$			

Typical calculation showing method of calculating per cent $CaCO_3$. Equivalent

---

Problem: Assuming that there have been no losses other than $CaCO_3$, calculate the number of pounds of fresh limestone that must have weathered to produce 100 pounds of the very rotten rock.

-C-

PLANT NUTRIENTS IN RESIDUAL SOILS STUDIED
(Adapted from Buckman)

Nitrogen

The soil nitrogen is carried very largely by the organic matter (original plant tissue and partially decayed portions). Its type of combination is very complex ranging from proteins (such as albumin) to amino-acids (such as alanin, CH_3 -$CHNH_2$ -COOH). Since higher plants can utilize but small amounts of organic nitrogen, the nitrogenous compounds must be simplified. Ammonia is first produced (ammonification) by biological action and later changed to the nitrate form (nitrification). The amount of nitrate nitrogen maintained in the soil has much to do with its fertility.

<u>Detection of nitrate nitrogen</u>. Obtain from stock room a test tube containing an inch of a humous sandy loam. Fill the tube to within an inch of the top with distilled water. Place thumb over end of test tube and shake for two minutes. Now add a little $Ca(OH)_2$, shake thoroughly and allow to stand for about five minutes.

Now filter the clear solution into a clean test tube until an inch of the percolate is collected. Pour this into a clean evaporating dish and evaporate to dryness over a small water bath.

When dry add fifteen drops of phenol-di-sulphonic acid to residue. Stir thoroughly with a glass rod. Then add one inch of distilled water as measured in a test tube. Mix thoroughly.

Neutralize solution with ammonia. The development of a yellow color is an indication of the presence of nitrates.

Phosphoric Acid and Potash

The phosphorus and potassium compounds in soils are rather insoluble. The soil sample must therefore be digested in strong acids before satisfactory tests can be made.

Obtain about 10 grams of soil from stock room. To this sample add about 10 cc. of HCl and 10 cc. of HNO_3. Set on tripod and gauze and bring to boil with frequent stirring. Allow to stand for a few minutes, keeping covered with watch glass.

Now filter and catch filtrate in beaker. The solution is now ready for testing.

Phosphorus -- Place 1/2 an inch of the solution in a test tube and add NH_4OH until a permanent precipitate occurs. Don't add too much ammonia.

Dissolve this precipitate with HNO_3 avoiding excess. Reduce solution to 1/2 an inch and add an equal amount of $(NH_4)_2MOO$. Heat gently. A yellow precipitate $(NH_4)_3PO_4 \cdot 12\ MOO_4)$ indicates the presence of phosphorus.

Potassium -- Place 1/2 an inch of the solution in a test tube and add NH_4OH until permanent precipitate forms. Make acid with acetic acid and reduce to 1/2 an inch. Now add as much sodium cobaltic nitrate as there is of solution. An orange yellow precipitate $(Co(NO_2)_2.3\ KNO_3)$ indicates potash.

Calcium

Calcium may exist in the soil as a carbonate, bicarbonate, sulfate or silicate. It is usually rather easily displaced by other bases.

Obtain a test tube from the stock room containing one inch sample of soil. Add two inches of a KNO_3 solution and shake very thoroughly.

Allow sample to stand for about five minutes and then filter until 1/2 an inch of clear percolate is obtained in test tube.

Test for calcium. Make solution acid with a drop of acetic acid. Now add a little ammonium oxalate $(NH_4)_2C_2O_4$. A white precipitate indicates calcium.

Practice 5

ORGANIC CONSTITUENTS OF THE SOIL

SOIL ORGANIC MATTER

Our study of the soil up to this point has been concerned only with the portion derived from the rocks. All soils contain more or less organic matter derived from partial decay of the plant forms supported by that soil.

The soil organic matter includes not only the original plant and animal matter that enters the soil but also the partially decayed portions of such compounds. (See note, page 99). It is, therefore, generally considered under two heads (1) the original tissue and (2) the partially decomposed materials.

PHYSICAL CHEMICAL EXAMINATION

Obtain a sample of soil organic matter (muck) from the stock room. Examine under hand-lens and note the indefinite character of the material. Observe the color and note that group 2 predominates.

The portion of the soil organic matter that can be dissolved in ammonia after treatment with dilute HCl is called humus. It is often considered as the more active portion of the soil organic matter.

Place a small amount of muck obtained from the stock room in a filter paper fitted in a funnel. Moisten well with dilute HCl and allow to stand a few minutes. Now wash with 25 cc. of distilled water. Discard percolate.

Now moisten the muck well with ammonia. After a few minutes wash with a few cc of distilled water. The black percolate is <u>humus</u>.

While the organic matter makes up only about 5% of the average soil it is very important in a number of ways (see page 8) as it is broken down into simple compounds by bacterial action. Chief among these simple compounds are NH_3 and CO_2. Beginning with a rather simple nitrogen compound the reaction, which is generally one of oxidation, may be illustrated as follows:--

$$\underset{\text{alanin}}{CH_3\text{-}CHNH_2\text{-}COOH} + O_2 = \underset{\text{acetic acid}}{CH_3\text{-}COOH} + NH_3 + CO_2$$

The ammonia is very quickly changed to the nitrate form (such as $Ca(NO_3)_2$, $NaNO_3$ etc.) by certain bacteria and the nitrogen thus becomes available to plants.

The CO_2 that is produced in such large amounts becomes the most important acid occuring in soil. It hastens solution, especially of such bases as calcium, to a marked degree.

Work out the answers to the following questions. You will be held for these in the written quiz of next week.

1. Name the two portions of the organic matter.

2. Explain what is meant by soil organic matter.

3. What is soil humus? How does it differ from organic matter?

4. Show how alanin might break down to ammonia and then write reactions showing the change of the ammonia to nitrates. See text, page 415.

5. What are these two processes called?

6. What is the importance of CO_2 and nitrate production?

ESTIMATION OF AMOUNT OF ORGANIC MATTER IN SOILS.

-B-

In this practice an estimate of the amount of organic matter in the stock soils will be made by determining the loss on ignition. Results obtained in this way are usually too high, for considerable water is driven out of hydrated silicates and CO_2 is expelled from carbonates. An accurate measuring of the total organic matter in a soil is almost impossible because of the varying composition of the material. Total carbon can be determined. The amount of CO_2 obtained from the oxidation of the carbon multiplied by the factor .471 is approximately the total organic matter. This factor was arrived at by determining the proportion of carbon in a large number of sa mples of extracted humus.

Each student will determine the loss on ignition of the stock soils furnished, and in one subsoil.

These soils will be only air-dry. It will be necessary, therefore, to determine the moisture (hygroscopic) in each stock soil and also in the subsoil.

Procedure:- Weigh out 5 grams of air-dry soil, 1 gram in case of peat in a small weighed aluminum cup. Dry at 105 degrees for at least 10 hours, cool in a desiccator, and weigh. Express the hygroscopic moisture as per cent of the dry weight. Tabulate the results.

Now transfer the dry soil to a weighed 3 inch evaporating dish and ignite for 30 minutes over a Bunsen burner, cool in a desiccator, and weigh. Express the loss on ignition as per cent of the dry weight. Tabulate the results.

1. Why is loss on ignition not a true measure of the amount of organic matter in a soil?

2. On which soil, black clay loam, or peat will loss on ignition more accurately represent the true amount of organic matter? Why?

Questions pertaining to hygroscopic water will be considered a little later when the water relation to soils is considered.

The interrelations of organic matter and mineral matter will be studied in appropriate exercises.

Exercise 6.

CLASSIFICATION OF SOILS ON BASIS OF TEXTURE.

The object of this practice is to help the student to become more familiar with some of the more important soil classes as recognized by the Soil Survey.

The basis of the separation and grouping of soils into classes is based primarily upon the varying amounts of sand, silt, and clay which they contain, or in other words, upon the mechanical composition of the soil.

The physical characteristics of soils as well as their chemical activities are determined in large degree by the sizes of particles present. The question of size of particle or texture can best be studied by separating a soil into its components. Such a separation is called a mechanical analysis. Study first part of chapter IV.

Learn the names of the separates and their ranges in size of soil particles.

In order to study soil separates it will be necessary first to make a mechanical separation of a soil which will be assigned.

-A-

Mechanical Separation of a Soil into Separates. (After Buckman)

Find on your desk a shaker bottle, containing 50 grams of soil. Add 10 drops of ammonia and fill to 6 oz. mark with water. Stopper and shake for five minutes. The ammonia and shaking are to cause deflocculation. The heavier the soil, the longer the shaking must be. Eight to twelve hours is not uncommon with clay.

After shaking wash down the sand sticking on the sides of bottle near the top, allow bottle to stand until only clay and silt are in suspension. (Obtain aid from instructor at this point). Carefully decant the suspended clay and silt, being careful to lose none of the sand.

Fill the bottle again with water, shake vigorously a few times, wash down material sticking on sides and allow to stand until all sand has settled. Decant clay and silt as before. As the sand carries down silt and clay, this operation must be repeated a number of times until the supernatant liquid is clear when the sand has settled. (See schedule on board).

When the sands are free from silt and clay wash them carefully into an evaporating dish. (Obtain aid from instructor at this point). Drain as free of water as possible. Place over a bunsen flame on tripod and asbestos. Heat gentle with constant stirring until dry.

When dry let cool. Place in soil sieve and separate into the five grades. (Obtain aid from instructor here.)

Study of the Soil Separates Obtained.

Pour the gravel and sand grades out on separate squares of paper and obtain samples of silt and clay from the stock room to go with them, giving seven separates into which a soil is divided in making a mechanical analysis.

Study these carefully under the hand lens with a view of later identifying the samples if presented unlabeled. The sands can all be seen with the naked eye, the very fine sand just barely. The sands have a gritty feel. The silt has a characteristic talcum-powder feel while the clay feel harsh. Why? Examine these separates until you are absolutely sure of the feel when dry.

Now add water to the very fine sand separate, the silt and the clay until they are moist, not wet. How is the feel changed and what is particularly characteristic of each? Study these three separates until the identification is absolute.

-B-

THE NAMING OF SOILS BASED ON THE PERCENTAGE CONTENT OF THE VARIOUS SOIL SEPARATES.

Soils are grouped according to the percentage content of the various soil separates into Soil Classes. Read par. 44 of text, and learn the common class names and note that these names are blanket terms for certain textural conditions. Read par. 45 and learn how to use the chart on page 85. Check up the soils of Table XVI until you are sure that you are using the chart correctly.

Each student will attach in his note book on suitable cross section paper a graphic representation of the mechanical composition of Sands, Fine Sands, Sandy Loams, Fine Sandy Loams, Loams, Silt Loams, Clay Loams, and Clays. Use the data on page 83 of your text book, and use a separate sheet for each soil.

Copy the following table in your note book, and determine the class name for each of the 7 soils.

	Mechanical Analyses						
	Soil						
Separate	A	B	C	D	E	F	G
Fine Gravel	2.3	.5	1.9	.2	1.2	.3	0
Coarse sand	10.9	2.7	4.7	.5	2.6	3.0	8.0
Medium sand	32.1	6.9	4.2	1.0	6.9	3.0	12.0
Fine sand	42.3	20.8	5.3	2.8	11.5	5.0	10.0
Very fine sand	9.7	32.4	27.1	8.6	14.7	6.6	25.0
Silt	1.7	20.3	45.7	70.6	38.5	27.1	10.0
Clay	1.0	16.4	11.1	16.3	24.6	55.0	35.0

A set of soils, representing seven soil classes, will now be provided. Make a careful hand and eye examination of these soils, noting their dominant textural and structural qualities in the dry and optimum moisture condition. In studying these soils in the moist condition, do not put water in the pans, but take a small portion of the soil and moisten it on watch glasses. Use an outline as shown and express observations in following terms.

Dominant textural quality.

1. Coarse grit.
2. Fine grit.
3. Intermediate mixture of gritty and non-gritty particles.
4. Velvety, flour-like feel.
5. Friability.

Dominant Structural quality.

1. No granulation - - - - - - (loose / compact (plastic when wet / cloddy when dry
2. Slight granulation.
3. Well granulated.

Soil Class	Dominant Textural Quality		Dominant Structural Quality	
	Dry	Moist	Dry	Moist

-C-

When you are sure regarding the identification of these type soil classes, work out the classification of the set of unknown soils, and record your answers in your note book in numerical order.

Practice 7

THE SOIL MAP

This practice is required to familiarize the student with soil survey maps, and soil types as found in the county assigned.

-A-

Each student will be furnished a county soil report with soil map attached. He will then be assigned three types of soil, the mechanical composition of which is given. Copy these data into the note book and then construct graphs by means of vertical bars to represent the mechanical composition.

-B-

Indicate the county and soil types and construct a profile of each type studied under A.

-C-

Each student will now be assigned a township of a county, the soil map of which is to be reproduced in the note book. Make this map carefully, locating soil types, streams, cities and villages, railroads, and number the sections. Use a different color for each soil type and give a legend indicating what type each color represents. Study following key to common series found in Wisconsin.

KEY TO THE COMMON SOIL SERIES FOUND IN WISCONSIN.

1. Loessial and Residual Section:

    A. Mainly Residual

    1. Dark Prairie
        a. Shallow ridge top soil - Dodgeville
        b. Deep soil on valley slopes - Bates

    2. Light Colored Timbered
        a. On limestone - Baxter
        b. On granite - Marathon
        c. On sandstone and shale - Boone

    B. Mainly Loessial

    1. Dark Prairie
        a. Terrace
            1. Poorly drained - Wabash
            2. Well drained - Waukesha or La Crosse

        b. Ridgetop - Marshall

    2. Light Colored Timbered
        a. Terrace - Lintonia
        b. Upland - Knox

II. Glacial Noncalcoreous Section:

A. Alluvial

1. Wet Dark
   a. sandy - Dunning
   b. Heavy - Whitman

2. Light Colored Well Drained
   a. Sandy - Plainfield
   b. Heavy - Antigo

B. Till on Sandstone or Shale

1. Light Colored
   a. Deep sandy - Coloma
   b. Shallow heavy - Vesper

C. On Granite or Trap

1. Red
   a. Iron range border - Mellen

2. Gray
   a. Sandy - Vilas or Chelsea.
   b. Heavy
      1. Loose open subsoil - Kennan.
      2. Tight mottled subsoil - Colby.

III. Glacial Calcareous Section:

A. Alluvial

1. Light Colored
   a. Poorly drained - Genesee.
   b. Well drained
      1. Sandy soil - Plainfield
      2. Heavy soil - Fox

2. Dark Colored
   a. Poorly drained - Clyde
   b. Well drained - Waukesha

3. From Red Lake Clay
   a. Poorly drained - Poygan.
   b. Upland - Superior

B. Till

1. Light Colored
    a. Upland timbered - Miami
    b. Thin sandy and gravelly soil - Rodman

2. Dark Prairie
    a. Upland prairie - Carrington

Geology:

Locate the county on a geological map of the state. What rock formations constitute the base rock in the county? Is the County in the glaciated or driftless part of the state?

Soils:

How many types of soil in the county assigned? In your township? Arrange these types in schematic form with descriptive matter as follo...

1. Soil Type
2. Class
3. Series
4. Geological Origin
5. Topography
6. Drainage
7. Physical classification and color of soil 0"-8", 8"-16", 16"-48"
8. Amount, kind and vertical distribution of organic matter.
9. Needed Improvements in Order of Importance

1. Read par. 46 of the text book and note carefully the answers to the following questions. You will be held for a written quiz over the questions of this exercise. (After Buckman)

1. Of what does a soil survey consist?

2. How is soil survey work reported? Two parts?

3. What six factors are considered in classifying soil in soil survey?

4. Which one of these is the geological classification already studied? See page 38.

5. Turn to laboratory chart and note the subdivisions commonly recognized within each of these six factors. Note that in proceeding from Temperature to Texture the classification becomes narrower.

6. What is a soil series? How is it named?

7. What is a soil type? How names?

8. What is the difference between the textural name of a soil and its type name? Illustrate by examples.

9. Why may there be a number of silt loams in any area with different type names?

10. What are the advantages of the type names above described?

2. Turn to the colored map opposite page 86, of the text book and work out the following:

1. Besides the soils shown in colors, list at least eight things that are represented on this map.

2. What are contours and what do they show?

3. What is the contour interval of this map?

4. What is the highest elevation on the map? Lowest?

5. Six soil types occur in the area. Locate them in the geological classification on page 38.

6. What are the approximate upper level figures for the glacial lake in this region?

7. Was the glacial lake deep or shallow compared with the lake of the Cayuga basin?

8. How account for muck in the uplands as well as in the valleys?

9. What soil type has the highest elevation? Why?

10. What soil type lies at the lowest level? Why?

3. Find on your desk a soil survey report from Illinois.

1. Turn to the soil map. What is its scale? In what other ways does it differ from the Bureau of Soils type of map?

2. Compare the written portions of the two reports as to character of the material presented.

3. Which type of report and map would probably be best for use by the farmer and county a gent?

--Soil Survey Classification--

I.	Temperature	Frigid TEMPERATE Subtropical Tropical
II.	Precipitation	HUMID Semi-arid Arid
III.	Agency	In situ -- Residual and Cumulose Gravity -- Colluvial Water -- Alluvial, Marine and Lacustrine Ice -- Glacial Wind -- Aeolian
IV.	Materials	Acid crystalline Basic crystalline Shales and slates Sandstones Limestones
V.	Special Properties other than texture	Drainage Color Organic matter Structure Acidity Nutrient needs
VI.	Texture	Size and proportinate mixture of particles.

FIELD TRIPS NO. I AND II.

Soils are classified into "soil series" on the basis of their geological origin, mode of formation, degree of weathering, color, character of the soil column (surface soil and subsoil), drainage conditions and other factors that they cause differences in the soil material. Soils are further separated into classes, the texture being the deciding factor. The "soil type" is the individual, and is, within reasonable limits, uniform throughout the area of its occurrence. The name of the soil type is made up of the series name and the class name - i.e., Miami the name of the series and silt loam indicating the class, the two make up type name of Miami silt loam.

The soil trip will acquaint the student with several types of soil, in two or more series. It will also acquaint the student with some of the common rock formations.

Equipment --

Soil augers, notebooks.

Observations --

Each student should study the character of the soils examined, noting the geological origin of the soil material, the mode of formation or accumulation of the soil, the topographic position of the soil, the evidence of weathering or alteration of the soil material since formation, the texture and structure, the depth and character of the soil column, particularly differences between surface and subsoil, the color of the soil and the subsoil, the amount of organic matter, the evidence of accumulations of lime or evidence of leaching, and other features that may help to distinguish the soil from any other body of soil that may be encountered.

The name of the soil series should be obtained from the instructor and the class determined, thus developing the type name.

Each student should make at least one boring to become familiar with the use of the soil auger.

In your report, write up the trip fully, giving the itinerary followed and a description of the soils encountered at each stop. Discuss fully the soil series and types studied on this trip.

QUESTIONS

1. What is a soil series?
2. What is a soil type?
3. What causes differences in the color of soils?
4. What causes differences between surface soil and subsoil?

REFERENCES.

Soil Survey Report for Dane County.

Bureau of Soils Bulletin 55 and 96.

Field Trip No. 3

It is highly important that students know something of the experimental work being conducted by the various departments in the College of Agriculture. This field trip will include a visit to one of the plots being operated by the Department of Soils.

Students will be required to make careful field notes having to do with the plot experiment and the results that are being secured.

Manure Experiments
Ison Field
Madison

This field experiment started in 1912, has been planned to furnish information regarding the following questions:

1. Should manure be plowed under or applied as a top dressing?

2. Are light frequent applications of manure better than heavy less frequent applications?

3. Where in a rotation should manure be applied?

A four year rotation of clover, corn, oats and wheat is practiced making it necessary to have four fields in order to have all the crops represented each year and also have all treatments repeated four times. Each field is divided into 8 plots which are treated as indicated below:

Plot	General Outline of Treatments on Acre Basis When in Clover	Corn	Oats	Wheat
1.	No Manure	No Manure	No Manure	No Manure
2.		Manure plowed under 16 tons		
3.	Manure top-dressed 16 tons			
4.	No Manure	No Manure	No Manure	No Manure
5.		Manure plowed under 8 tons		Manure plowed under 8 tons
6.		Manure top-dressed 8 tons		Manure top-dressed 8 tons
7.	No Manure	No Manure	No Manure	No Manure
	Manure top-dressed 8 tons	Manure plowed under 8 tons		

Practice No. 8

Soil Structure

Before coming to the laboratory read chapters six and seven in the text book.

The arrangement of soil particles is very important is determining the chemical and physical nature of a soil. Water content, air movements, and other soil processes are affected by the way soil particles are grouped together.

Soil particles are usually grouped into clusters, held together when dry by a cementing material. This cementing material is present especially in clays and in soils with a high percentage of organic matter, and is known as a "colloid". Other cementing materials may be present in soils but they do not function as colloids in the production of a "crumb" structure except as they affect the natural behavior of the colloids, or act as cements directly.

Soils contain mineral and organic colloids. Soils with a high percentage of clay manifest certain properties because of their colloid content. Sands contain, as a rule, a low percentage of colloid matter; therefore, they do not manifest the same properties as clay soils with respect to the formation of a "crumb" structure.

At this point become thoroughly familiar with the common properties of colloids, and with the properties imparted to soils as a result of their colloidal content. Learn the forces which tend to develop a granular structure in soils before proceeding with the practice.

Each student will be provided with a set of eight soil pans. Three 150 gram lots of each soil are required. Add water from 100 c.c. cylinder so as to obtain water content as expressed in the table. After adding the water mix each soil thoroughly with your fingers. Now describe the tilth developed in each pan as follows:

1. Loose (No or very slight granulation).
2. Crumbly (Good granulation)
3. Plastic (Granules too large - adhering to each other).
4. Puddled (Granulation broken down).
5. Excess free water.

After describing each soil, mold each sample into a ball, place on a board, and let dry until next laboratory period. Now break open each ball of soil and describe the ease with which it is broken as follows:

1. Crumbled on standing.
2. Easily crumbled.
3. Crumbled with difficulty.
4. Baked into a hard lump.

Tabulate data as indicated.

Description of Structures Developed by Wetting and Stirring.

Soils Low in Organic Matter	Water added as per cent of air-dry soil.		
	12½%	25%	37%

Arrange a similar table to describe the condition after molding and drying.

Each student will make observations on the eight stock soils provided. Arrange these into two groups according to their organic matter content.

List the soils studied in a column and place opposite them the water content which in your opinion permits the best tilth.

1. What is the effect of organic matter on soil structure?

2. On which soils does an excess of water cause an extremely bad tilth? Why?

3. What is the effect upon the tilth of cultivating very wet soils?

4. Which classes of soils may be safely plowed within wide moisture limits?

5. How can the farmer secure good soil structure?

Write a brief, concise discussion of at least 600 words on the following topic, "Natural and artificial agencies that produce good soil structure."

References:

Soil Physics and Management - Mosier and Gustafson.
The Nature and Properties of Soils - Lyon and Buckman.
Productive Soils - Weir.
Soils and Fertilizers - Lyon.

Practice No. 9

The Determination of the Volume Weight (Apparent Specific Gravity), and the Porosity of Soils.

Each student will be required to pass an examination over the contents of chapter IV of the text before he will be allowed to proceed with this practice. The specific physical properties of a soil which are manifested because of the textural and structural make-up, such as specific gravity, volume weight, pore space, and internal surface, are important from the standpoint of crop production. Each student will determine the volume weight and the porosity of the eight stock soils provided.

Secure from the store room one brass volume-weight cylinder, one special galvanized iron funnel to fit, and a large cork stopper with which the tube ma y be tightly stoppered. Return these three pieces of apparatus to the store-room at the close of your laboratory period

Obtain the weight, volume, and number of the empty cylinder. Place the funnel in the cylinder. Fill the cylinder with soil to the mark by gently pouring soil from a cup into the cylinder, resting the edge of the cup on the edge of the funnel. Do not compact the soil during this process. Remove the funnel and weigh the soil and cylinder on the l arge Troemner balance. Stopper tightly, and let drop six successive times through a space of 6 inches onto an asbestos plate. Pour in soil just to the mark and let drop three times through a space of three inches. Add soil until the cylinder is filled just to the mark, but do not compact again. Remove funnel and weightthe cylinder plus compacted soil. Make two determinations for each soil, and a verage the results. Since these soils are only air dry it will be necessary to calculate the weight of the water free soils. Use the figures for hydroscopic moisture obtained in practice No. 5. Calculate the apparent specific gravity, and the pore space of the eight stock soils, arranging the data for each soil according to the following scheme.

	Sand		Arrange the soils according to organic matter content.
	Loose	Compact	
Weight of cylinder and soil 1			
2			
Average weight of cylinder and soil			
Weight of cylinder			
Average weight of air dry soil			
Percent of Hygroscopic moisture			
Weight of water free soil			Give type calculations in full
Volume of cylinder			
Apparent specific gravity			Give formula used to arrive at the results
Pore space			Give formula used to arrive at the results

The absolute specific gravities of the soils are as follows:

Sand	2.65	Brown silt loam	2.60
Fine sand	2.65	Black silty clay loam	2.50
Sandy loam	2.64	Red clay	2.57
Gray silt loam	2.62	Peat	1.50

Calculations

1. Calculate the weight of a cu. ft. of each soil.

Problems

1. Calculate the specific gravity of a soil from the following data

Volume of picnometer - 50 cc.
Weight of picnometer - 20 grams.
Weight of soil used - 6 grams.
Weight of picnometer + soil + water = 73.5 grams.

2. A core of moist field soil one tenth of a cu. foot in volume weighs 12.5 pounds. One hundred pounds of this moist soil contains 20 pounds of water. Calculate volume weight.

3. A soil has a pore space of 50% and a specific gravity of 2.7. What is its volume weight?

Questions

1. What is the relation of soil texture to the total amount of pore space? To the size of the pores?

2. What is the relation of soil structure to the total amount of pore space? To the size of the pores?

3. What is the effect each of the following field practices upon the amount of pore space and upon the size of the pores: plowing, harrowing, rolling, subsoiling, deep-tilling, dynamiting, under-draining, single-cropping, rotation of crops? Explain in full.

4. What is the relation of the amount of organic matter to pore space?

5. Why is the apparent specific gravity of a sand higher than that of a silt loam or clay loam?

Practice 10

Comparison of Capillary Rise of Water in Different Soil Types

The entire class will observe the results of one experiment and will copy posted data and record the same in their note books. Observe heights of water at the end of 1 hour, 2 hours, 3 hours, 6 hours, etc. for a period of about 10 days. Note time schedule on bulletin board.

The following soil type will be used: Plainfield sand, Miami silt loam, Miami silt loam and a layer of organic matter, Carrington silt loam, Clyde clay loam, Superior clay, Miami fine sandy loam.

After recording the data obtained, plot on a sheet of cross section paper, curves showing the rate of rise of water, plotting days as abscissae, and heights to which water rose as ordinates. Letter each curve neatly.

After you have properly drawn the curves, answer the following questions:

1. Will moisture that is 10 feet below the surface of the soil ever become available for plants whose root systems are entirely in the surface two feet?
2. What is the relation between the capillary movement of soil moisture and the methods used for preventing the loss of soil moisture?
3. When should coarse manure or coarse green manuring crops be plowed under? Why?
4. What is the relation of texture to capillary rise of moisture?

Practice 11.

Maximum Retentive Power of Soils for Water

Read paragraph 90 of the text before beginning this practice.

Carefully equip four 4" funnels with 18 c.m. filter paper, wetting filter paper with water to insure close fitting and saturation.

Weigh out a 50 gram lot of each of the following types of soil: Plainfield sand, Miami fine sandy loam, Miami silt loam, and Carrington silt loam.

Transfer each lot into a 250 c.c. beaker. Add to the sand and to the fine sandy loam 25 c.c. of water, to each of the silt loams 50 c.c. of water.

Stir each lot thoroughly and transfer the wet soil slowly and carefully onto the prepared filter paper being careful not to lose any of the soil or water.

Cover samples with watch glasses and allow to drain for 15 minutes, being careful not to lose any of the water that percolates through the soils. Now measure the drainage water in each case and calculate the amount of water held by each soil. Tabulate the results. Since in this method the results are about double the actual field capacity, divide by two and express the water held as the percentage on the dry basis and also as surface inches.

Problems

Methods of Expressing Soil Moisture

Percentage Expression

A 50 gram sample of moist soil loses on heating 5 grams of water. Express this water on the moist basis and dry basis respective.

Volume Expression

A soil weighs 2,000,000 pounds per acre 8 inches and contains 20% of water dry basis.

Express the moisture content therein by the three possible volume expressions.

Calculate the volume weight of the above soil.

Taking a Sample of Soil.

Frequently farmers wish to know the lime needs of their soils for growing alfalfa or other leguminous crops. The Soils Department will make acidity tests free of charge if samples are sent according to the following directions:

In taking a sample of soil, any sod, or manure, or other rubbish on the surface should be scraped off before the sample is taken. The soil should be taken to a depth of 3 or 4 inches, but not below the plowed layer unless the subsoil is to be tested.

Small portions should be taken from 5 or 6 different places in the field; so as to get a pound or two of soil in all. This should be sufficiently dried; so that it can be well mixed and from this mixture a sample of about one-half pound should be sent, placing it in a well cleaned tin can.

If the field vaties widely in fertility or topography, it is best to take several entirely separate samples from different parts of the field. If part of the field is high land, and part low land, a separate sample should be taken from both places, and in no case should the soil from high l and be mixed with the soil from low land in making up a sample, as the results then will not mean anything. Samples from different fields should never be mixed. Different parts of the same field, and especially of the different fiel ds on the same farm, vary greatly in acidity. If more than one sample is sent, be sure that there is a number on each package corresponding with the number in the letter describing the samples.

Always have your soil tested before applying lime because some soils do not need liming. It is very profitable to put lime on acid soils, but a waste of time and money to put it on soils that are not acid.

Collect the following information when taking samples for analysis.

1. Name of owner _

2. Address of owner _

3. Date of shipping soil _

4. By way of what railroad _

5. Number of sacks of soil shipped _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

6. Full information concerning the cropping history and manurial treatment of the field. As far as possible this information should include the following:

   (a) Number of years land has been under cultivation since cleared_ _

   (b) Cropping history. Rotation usually followed:_ _ _ _ _ _ _ _

   _

   _

   _

   (c) Average yields of crops usually grown. (Express in bushels per acre, or tons per acre) _ _ _ _ _ _ _ _ _ _ _ _

   _

   _

   (d) Has the field ever received any special treatment such as liming, commercial fertilizers, etc?_ _ _ _ _ _ _ _ _ _ _ _ _

   _

   (e) Is there any trouble getting stands of clover?_ _ _ _ _ _ _

   _ _ _ _ _ _ _ _ _ _ _ _of alfalfa?_ _ _ _ _ _ _ _ _ _ _ _ _ _ _

   (f) Is the field well drained?_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

   _

Exercise 12

Absorptive Properties of Soils

1. Causes of Absorption -- Textural relations (Pars. 139 & 140)

Weigh out five gram portions of Plainfield sand, Miami sandy loam and Miami silt loam resp. Place in evaporating dishes. Add 10 cc. of solution A of $CaH_4(PO_4)_2$ on each.

Mix each sample thoroughly with stirring rods and allow to stand 3 minutes. Now decant liquid onto separate filter papers held in funnels and filter.

Catch about one-half an inch of each percolate in test tubes.

Test for phosphorus in each solution by adding a drop or two of HNO_3 and then about half as much ammonium molybdate as there is of percolate. Warm gently. Yellow ammonium-phosphomolybdate appears in proportion to the phosphorus present.

--Questions--

1. Which soil has the greater absorption? Why?
2. What two types of absorption occur in soils?
3. Give practical examples of each.

2. Substitution of Bases. Par. 142

Fit out two funnels with filter paper as before. Wash filter paper with distilled water.

Fill each filter half full of a soil which contains plenty of available lime. (Clyde silty clay loam). Hollow well in the center.

To one sample add distilled water and to the other add a solution of KNO_3. Add slowly. Catch percolate in test tubes, collecting about one-half an inch in each case.

Now test for calcium in each by adding about a cubic centimeter of ammonium oxalate solution to each percolate.

--Questions--

1. Explain the results obtained using chemical reactions.
2. Why might nitrification increase the availability of the lime in the soil?

3. Absorption of Phosphoric Acid by Soil. Pages 264 and 457.

Weigh out two 5 gram portions of Miami silt loam from stock room and one 5 gram portion of the same soil treated with calcium hydroxide. Place in evaporating dishes. Use solutions of soluble phosphoric acid ($CaH_4(PO_4)_2$) as follows:

Add 10 cc. of Solution B (carrying 1.2 mg. P_2O_5 per 1 cc.) to one sample of the original soil. To the other sample of the original soil add 10 c.c. of Solution C. (carrying 3 mg. of P_2O_5 per 1 c.c.) Make the same addition of Solution C to the sample treated with $Ca(OH)_2$. Mix thoroughly with stirring rods.

After standing 3 minutes pour the mixtures into their respective filter papers which have been fitted into funnels and moistened slightly.

Catch exactly one-half an inch of percolate in each case. Test for phosphorus by adding two drops of HNO_3 and five c.c. of ammonium molybdate solution. Heat gently over a bunsen flame. If phosphorus is present a yellow precipitate will appear, which is ammonium-phospho-molybdate.

--Questions--

1. What reactions take place when acid phosphate ($CaH_4(PO_4)_2$) is added to a soil? See page 457.

2. Why have plenty of active calcium in the soil when acid phosphate is added?

Practice 13.

The Determination of the Total Amount of Phosphorus Contained in Cropped Soils

Each student will determine the total amount of phosphorus in two soils. One of these soils represents a field that is fertile; the other soil represents a field that is infertile. These soils are marked A and B respectively.

Method:

Mix 4 g. of soil with 6 g. of magnesium nitrate $Mg(NO_3)_2.6H_2O$ in a 50 cc. porcelain crucible. Place the crucible on a triangle in a slightly inclined position and place a low flame under the crucible in such a position that the upper portion of the contents is heated first. On first heating, the mixture bubbles and foams a great deal and there is great danger of the material running over, especially if the heat is applied at the bottom of the crucible. For soils high in organic matter it is best to stir up the mass with a glass rod as soon as the magnesium nitrate melts in order to quickly wet up all the material and hasten the process. Gradually raise the flame and when the mass becomes quiet and brown fumes cease to escape, put on the cover and heat with the full flame of a good Bunsen burner for 20 minutes. Cool and loosen the mass from the sides with a spatula, and pulverize the lumps with the small end of a pestle. Brush out the contents on a piece of smooth paper and transfer to a 150 cc. Erlenmeyer flask with a 50 cc. capacity mark. Add 15 cc. of concentrated HNO_3 to a flask. In case it is difficult to remove the last traces of material reasonably well from the sides of the crucible the HNO_3 may first be put into the crucible and let stand for a few minutes and then transferred to the flask. This will remove any phosphorus and also make it easy to clean the crucible. Heat the flask under the hood on a sand bath or over a flame so that contents boil moderately for 15 minutes. The flask should be shaken often while heating to prevent caking and spattering. Dilute to 50 cc. and shake well. Filter on dry filter paper and transfer 25 cc. of filtrate to 300 cc. Erlenmeyer flask. Add 12 per cent NH_3 (1 cc. con. reagent dilute to 2.3 cc.) from a burette with shaking until a permanent yellow colo or slight precipitate forms and note amount of NH_3 used. Add enough NH_4NO_3 solution (1/2 g. per cc.) from burette to make with the NH_3 added 10 cc. in all. Then add 4 cc. of con. HNO_3 and shake. Place the flask in a water bath and heat to 58°. Add 10 cc. of filtered Molybdic solution. Shake gently by whirling and let stand in a water bath at about 40° for 1/2 hour. Do not let stand over night or more than one hour. Filter on 9 cm. ashless filter paper. Wash eight times with 3 per cent NH_4NO_3 rinsing out the flask with the first four washings. Take 18 cc. of solution D and make up to 300 cc. with distilled water. Then wash four times with distilled water. Carefully transfer filter paper and contents to original flask. Add from a burette 10 cc. standard NaOH. For soils very high in phosphorus 15 cc. will be needed. Close with a good stopper and shake until yellow precipitate is dissolved and filter paper is well broken up. Carefully wash off the stopper with CO_2 free water and also wash down the sides of the flask. Do not use more than 25 cc. of water. Add 1/2 cc. of phenolphthalein and titrate back with standard HNO_3 till solution is colorless. One cc. of 0.148N alkali consumed represents 0.2 mg. of phosphorus. Calculate phosphorus to percentage and pounds per acre.

Tabulate your results as follows

	Good Soil	Poor Soil
C. C. St'd alkali added		
Equivalent to .148 N. alkali		
C. C. St'd acid used		
Equivalent to .148 N. acid		
C. C. .148 N. alkali consumed		
Phosphorus content in per cent		
Pounds of phosphorus over an acre of soil 8" deep		
Amount of phosphorus taken out of the soil by a rotation of clover corn, oats.		
Assuming that 1% of the total phosphorus becomes available each year, what would be the probable maximum yields of corn that could be grown on each soil.		

Practice 14

The Determination of the Degree of Soil Acidity

The weathering processes in humid regions tend to deprive soils of their native carbonates. Cultivation and cropping add to the losses. Since soil acidity is a widespread condition, methods for its detection and estimation are useful.

Various methods of testing soil for its acidity are in vogue and differences in opinion as to their accuracy still exist. This is due to the fact that the true nature of this soil ailment is not yet fully established and by no means common knowledge. For this exercise the Truog method of detecting soil acidity will be used. This is a rapid method, simple in manipulation and it permits estimation of quantitative results accurate enough for practical purposes.

Procedure:

Ten grans of mineral soil, or $2\frac{1}{2}$ grams of peat are measured out and placed in a 300 cc. Erlenmeyer flask. Dip the small brass measuring spoon into the bottle of chemicals, strike off just level full with a spatula or knife, allowing the excess to fall back into the bottle; then transfer the spoonful of chemicals (Barium chloride and zinc sulphide) to the soil in the flask. Add 100 cc. of distilled water or rain water, shake the flask until contents are well mixed, then place on a ringstand over a wire gauze and heat gradually. In about five minutes boiling will begin, if the flame is properly regulated. If too violent frothing occurs in the start, causing foam to rise up in the neck of the flask, remove the flask from the flame for a few seconds until the foam subsides. After the contents have boiled one minute (exact), place a strip of lead acetate paper, which has been moistened with a few drops of distilled water, across the mouth of the flask and allow it to remain two minutes (exact). Then remove paper and turn flame out. If the soil is acid, the under side of the paper will be darkened. After drying the paper, compare it with the color chart and determine the degree of acidity. From the degree of acidity determine the amount of lime needed for growing clover by reference to the lime chart. Finally record your results as indicated in the outline, and paste the test paper in the place designated.

The student will make determinations of the degree of acidity in eight different soils. Answer the questions.

Adapt the following outline.

Soil Class	Test paper and Degree of acidity	Amount of limestone for clover growing	Amount of limestone for alfalfa growing

1. What two factors contribute to producing the degree of coloration shown on the test paper?

2. Why does this test give a better index to the amount of lime which should be used than any of the so-called lime requirement methods?

3. State and explain the effect of the following upon the test:

   (a) Using water from Lake Mendota.

   (b) Boiling more or less than one minute during first boiling period.

   (c) Boiling more or less than two minutes during the second boiling period.

4. What per cent of Wisconsin Soils are acid?

5. If you had no distilled water with which to make the soil acidity test, what would you do?

6. Write a report covering bulletins 312 and 361.

Practice 15

Agricultural Lime and Its Use

The term lime correctly used refers to CaO. In its popular and agricultural sense it refers to all calcium and magnesium compounds applied to the soil to correct acidity.

Ground limestone is produced by crushing limestone of suitable purity. Its effectiveness up to a certain point depends upon fineness of grinding, neutralizing value expressed as per cent of calcium carbonate and solubility.

Each student will determine:

1. The mechanical composition of one assigned sample of ground limestone.

2. The relation of fineness of grinding to rate of solution.

3. The relation of fineness of grinding and quality to rapidity of neutralization of acid soils.

Note:- The class will analyze the 14 samples. The results of all determinations must be recorded in note books.

Procedure:

1. In the top sieve of the set furnished you, arranged in order of fineness with the coarsest uppermost, place 100 gms of the sample of ground limestone assigned. Place cover on top of set and shake until no more limestone passes any of the sieves. Now weigh the separates accurately on the analytical balance. The sum of the separates should approximate 100 grams. Add up the percentage which passed the 60 mesh sieve. Since 50% of a good quality limestone will pass a 60 mesh sieve you have made the first test in determining the value of a given sample for correction of soil acidity.

Arrange data in tabular form as follows:

Mechanical Composition of Sample No.______.

Separate	Weight of Separate	Per Cent of Separate
Held in 20 mesh		
Passing 20 - held on 40		
Passing 40 - held on 60		
Passing 60 - held on 80		
Passing 80 - held on 100		
Passing 100		
Passing 60 and finer		

2. To $2\frac{1}{2}$ grams (exact) 20 mesh sample of limestone assigned placed in a clean beaker, add 50 cc. of standard HCl (Pipette). Let stand for 15 minutes, stirring at intervals of 5 minutes. At the end of 15 minutes pour the sample onto prepared filter paper, catching the filtrate in a clean beaker. Transfer a 10 cc portion of the filtrate (Pipette) to a clean beaker and titrate the excess acid with standard alkali, using Methyl orange as the indicator. Calculate the number of cubic meters of acid neutralized by the limestone separate.

Tabulate the results as follows:

Relation of Quality of Limestone to Rate of Solution

	c.c. Alkali	cc. acid neutralized
10 c.c. Original HCl solution		
HCl solution partly neutralized by 20 mesh limestone No. 1		
HCl solution partly neutralized by 20 mesh limestone No. 2		
HCl solution partly neutralized by 20 mesh limestone No. 3		
Etc.		

3. Add to a 100 gram sample of acid soil supplied, an amount of 100 mesh limestone equal to an application of 5 tons per acre 8 inches (2,000,000 lbs.) using the grade of limestone assigned. Mix the limestone intimately with the soil and add to each the same amount of distilled water (25 cc.), sufficient to moisten the soil well but not make it wet. Cover the container with a watch glass to prevent evaporation and let stand until next period. Then run two Truog acidity tests on the sample and one on the original soil. Paste one test paper in notebook and paste the other test paper on chart provided for exhibition, and determine the degree of acidity by comparison with a chart. Compare the degree of acidity of all fourteen treated soils and record results in note book. It would be of interest to study different degrees of fineness of materials to rate of neutralization of acid soils, but it is obvious that the finer the material the greater the rate of neutralization.

Relation of Quality of Limestone to Rapidity of Neutralization of Soil Acids.

	Test Paper	Degree of Acidity
ZnS-lead acetate test on acid soil		
ZnS-lead acetate test on same soil after 1 period's contact with 5 tons per A. of 100 mesh limestone No. 1		
ZnS-lead acetate test on same soil after 1 period's contact with 5 tons per A. of 100 mesh limestone No. 2		
Etc.		

--Lime Problems--

1. Ground limestone is often guaranteed in terms of "calcium carbonate equivalent", the magnesium carbonate being calculated to calcium carbonate.

Calculate the equivalent $CaCO_3$ of the following limestone:

$CaCO_3$ - -	48%	Ca = 40	
$MgCO_3$ - -	43	Mg = 24.3	
Impurities - -	9	C = 12	
	100	O = 16	
		H = 1	

2. Which is the more valuable of the limes quoted below as a neutralizing agent?

		$CaCO_3$ - -	38%
$CaCO_3$ - -	47%	$Ca(OH)_2$ - -	5
$MgCO_3$ - -	34	$MgCO_3$ - -	38
Impurities	19	Impurities	19
	100		100

3. Check up the calculation at bottom of page 369. Also see table of factors on page 367. It will be necessary to understand this calculation in order to solve the next problem. Work it thru carefully.

4. Calculate the amount of burned lime (carrying 90% CaO and 5% MgO) necessary to equal an application of 2000 pounds of limestone analyzing 90% $CaCO_3$ and 5% $MgCO_3$)

5. A farmer receives the following quotations:

Burned lime, 80% CaO equiv.	$ 5.50
"Hydrate", 95.2% $Ca(OH)_2$ equiv.	6.00
Limestone, 90% $CaCO_3$ equiv.	2.75
Limestone, 60% $CaCO_3$ and 21.1% $MgCO_3$	2.65

Freight, haul and application is to cost $2.00 per ton.

Which form of lime would give the greatest neutralizing power for every dollar expended?

6. Why is $MgCO_3$ more effective as a neutralizing agent pound per pound than $CaCO_3$?

Practice No. 16

STUDY AND IDENTIFICATION OF COMMON FERTILIZER MATERIALS AND COMPOUNDING COMMERCIAL FERTILIZERS.

(After Albrecht and Buckman)

Primarily the function of commercial fertilizers is to add plant nutrients to the soil, usually in a more readily soluble form than those already present in large quantity. Other beneficial effects may result but they are of secondary importance.

Prepared fertilizers, commonly found on the market are designed to supply either some or all of the three elements, nitrogen, phosphorus and potassium, whose addition in soluble form usually increases plant growth. These elements are supplied by various ingredients, and it is upon the composition and solubility of these plant food carriers that the value of the fertilizer depends. For this reason a knowledge of the properties of the common fertilizer materials is of interest to every user of fertilizers and of valuable aid in their purchase.

A study will be made of the different ingredients that enter into commercial fertilizers. Labelled samples will be studied and their characteristics tabulated. Fill in the table for the different materials. After you are thoroughly familiar with these, you will identify unlabelled but numbered samples of them as individuals or mixed samples, to be recorded in the sheet given herewith.

The use of fertilizer is developing so rapidly in Wisconsin that agricultural students should be familiar with their application and methods of mixing. Some time will be given to the calculation of fertilizer formulas, and the method of mixing fertilizers.

In calculating fertilizer formulas students will be required to determine the amount of given raw materials necessary to supply the needed nitrogen, phosphorus and potassium for mixing certain standard fertilizer formulas. The following data are necessary in making these calculations.

Fertilizers are usually designated by formulas such as 2-8-2, 2-12-2, etc. The first figure refers to NH_3 not N. N may be transformed into its equivalent in NH_3 by multiplying by 1.21. The second figure refers to available P_2O_5 not P. P may be transformed to its equivalent in P_2O_5 by multiplying by 2.29. The third figure refers to soluble K_2O not K. K may be transformed to the equivalent of K_2O by multiplying by 1.20.

Find on the center table a set of fertilizers and various forms of lime.

Examine each material in the order indicated and record the

Name of Fertilizer	Availability of Fertilizing Constituent	Per cent of Fertilizing Elements			Odor, Color Physical Condition etc.	Application per acre	Cost per acre

Problems

1. Using sodium nitrate containing 15% N., 16% acid phosphate and muriate of potash containing 48% K_2O, how much of each together with filler must be used in mixing 5 tons of: (a) 2-10-2, (b) 4-8-4?

2. Using dried blood containing 12% N. acid phosphate containing 6.8% of P., sulfate of pot ash containing 52% K_2O, how much each with filler must be used in mixing 5 tons of (a) 3-8-5 and (b) 4-10-6?

3. A farmer wishes to apply the equivalent of 150 pounds per acre of a 2-10-2 fertilizer. He can get from the local dealer the following: (a) Tankage containing 7% NH_3 and 5% P_2O_5, acid phosphate containing 16% P_2O_5 and muriate of potash containing 48% K_2O. How much does he need of each to mix a ton of 2-10-2 and how much should he apply per acre if he puts in no filler?

(b) Leather Scrap containing 6% N. and 2% P_2O_5, acid phosphate containing 14% P_2O_5 and sulphate of potash carrying 50% K_2O, how much must he apply per acre without filler to equal 150# of a 2-8-4?

Table of Composition

Commercial Fertilizer Materials

Nitrogen Carriers Per cent NH_3	Phosphorus Carriers Per cent P_2O_5	Potash Carriers Per cent K_2O
Sodium Nitrate----19	Acid Phosphate----14-16	Muriate of Potash---46-48
Ammonium Sulphate-22-25	Rock Phosphate----26-30	Sulphate of Potash---48-52
Dried Blood------- 8-16	Treble Phosphate--46-48	Wood Ashes--5
Tankage----------- 6-11	Steamed Bonemeal--22-28	
Leather Meal------ 6-8	Raw Bone Meal-----20-25	
Hoof & Horn Meal--15-17	Basic Slag--------16-18	

The following reports should be completed at this time.

Report 1. Use of Phosphorus.

1. Name of experimenters _

   (If cooperative or demonstrative test give name and position of supervisor as well as name of farmer). _

2. When and where (State & County) was experiment conducted

   _

3. Name of publication in which experiment was described _ _

   _

4. Date of publication _

5. Area of plots or fields under experimentation _ _ _ _ _ _

6. Form of phosphorus fertilizers used and per cent of P contained therein _

7. Amount of phosphorus fertilizer applied per acre, and equivalence in pounds of P _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

8. Cost of fertilizer per ton _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

9. Crop grown _

10. Yields per acre

    (Straw and grain, or corn and) Phosphate Plot _ _ _ _ _
    (   )
    (Stalks separately if possible) Untreated Plot _ _ _ _ _

11. Increase due to phosphorus _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

12. Value of increase due to phosphorus _ _ _ _ _ _ _ _ _ _ _ _

13. Cost of fertilizer per acre _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

14. Net gain per acre, (deducting cost of fertilizer) _ _ _ _

15. Soil (Classified as to texture) _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

16. Soil Reaction (acid or neutral) _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

Report 2. Use of Lime.

1. Name of experimenters_ _

?. (If cooperative or demonstrative test give name and position of supervisor as well as name of farmer)._ _

2. When and where (State & County) was experiment conducted _ _

_ _

3. Name of publication in which experiment was described _ _ _

_ _

4. Date of publication _

5. Area of plots or fields under experimentation _ _ _ _ _ _ _

6. Form of lime used and per cent of CaO contained therein _ _

_ _

7. Amount of lime applied per acre, and equivalence in pounds of $CaCO_3$ _

8. Cost of lime per ton _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

9. Crop grown _

10. Yield per acre. (Limed Plot _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
(Untreated Plot _ _ _ _ _ _ _ _ _ _ _ _ _ _

11. Increase due to liming _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

12. Value of increase due to liming_ _ _ _ _ _ _ _ _ _ _ _ _ _

13. Cost of lime per acre _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

14. Net gain per acre (deducting cost of fertilizer) _ _ _ _ _

15. Soil (classified as to texture)_ _ _ _ _ _ _ _ _ _ _ _ _ _

16. Degree of acidity of soil _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

Report 3. Use of Legumes.

1. Name of experimenters _

   (If coöperative or demonstrative test give name and position of supervisor as well as name of farmer). _

2. When and where (State & County) was experiment conducted _ _

   _

3. Name of publication in which experiment was described _ _ _ _

   _

4. Date of publication _

5. Area of plots or fields under experimentation _ _ _ _ _ _ _ _

6. Legume grown _

7. How many seasons did the legume occupy the soil? _ _ _ _ _ _ _

8. Non-legume following legume _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

9. Yield of non-legume following legume _ _ _ _ _ _ _ _ _ _ _ _ _

10. Yield of non-legume following non-legume _ _ _ _ _ _ _ _ _ _ _

11. Increase per acre due to legumes _ _ _ _ _ _ _ _ _ _ _ _ _ _

12. Value of increase due to legumes _ _ _ _ _ _ _ _ _ _ _ _ _ _

13. Cost of legume seed per acre - stating number of pounds of seed sowed per acre _

14. Net gain per acre (deducting cost of seed) _ _ _ _ _ _ _ _ _

15. Soil (classified as to texture) _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

16. Soil Reactions (acid or neutral) _ _ _ _ _ _ _ _ _ _ _ _ _ _

17. Supplementary treatment.

    Mineral fertilizers applied per A.

    ________ lbs. P in form of _______, lbs. of _______________

    ________ lbs. K in form of _______, lbs. of _______________

    Lime applied per A.

    ________ lbs. $CaCO_3$ in form of _______, lbs. of ___________

Practice No. 17

The Determination of Nitrate Nitrogen in Soils.

Object - A study of the absorption of nitric nitrogen by crops.

Each student will determine the amount of nitric nitrogen in 3 soils differing in cultural treatment. These soils will be brought to the laboratory just before the class meets to perform the work of determining the nitrate nitrogen content of each soil.

Reagents

1. Phenoldisulphonic acid. - Profided

2. Dilute Ammonium hydroxide - Provided

3. Standard nitrate solution. - Provided

4. Standard Colorimetric solution. Evaporate 10 cc. of standard nitrate solution to dryness in a porcelain dish on the steam bath, treat as in analytical procedure with 3 cc. of phenoldisulphonic acid, 15-25 cc. of cold water and dilute NH_4OH till yellow color is permanent and solution is slightly alkaline. Dilute to 100 cc. The solution now contains 1 p.p.m. of N.

5. Normal Copper Sulfate Solution. - Provided

ANALYTICAL PROCEDURE

(H. J. Harper's modification)

Pulverize and mix the sample of soil and pass it through a four mesh sieve. Weigh out 50 g. of soil (in case of peat 25 g.) for a moisture determination. Weigh out a similar amount for the nitrate determination and place it in a pint Mason jar or 500 cc. wide mouth bottle. Add 250 cc. of water containing 5 cc. of the normal copper sulfate solution provided and shake 10 minutes. If the soil is not very acid and does not give a highly colored solution add 1/2 g. of $Ca(OH)_2$ directly to the soil and solution and shake 5 minutes more to precipitate the copper. Filter on a dry filter and discard the first 20 cc. of filtrate. If the soil is very acid or gives a highly colored solution, allow to settle after the first shaking of 10 minutes and decant about 150 cc. of the supernatant liquid into a flask. Add to this flask 1/4 g. of $Ca(OH)_2$, shake 5 minutes, filter on a dry filter and discard the first 20 cc. of filtrate. In either case transfer 10 cc. (Use 25 cc. or more if nitrate content is low) portions with a pipette to 3 inch evaporating dishes. Test the remaining filtrate with phenolphthalein and if not alkaline, add 5 cc. of saturated $Ca(OH)_2$ solution to each portion in the evaporating dishes, but if alkaline do not add the $Ca(OH)_2$ solution. Place the dishes on the steam bath and evaporate to dryness. Cool the dishes and then add rapidly 3 cc. of phenoldisulphoric acid directly to the center of each evaporating dish and then rotate the dish in such a way that the reagent comes in contact with all the residue.

Let reagent act 10 minutes and then add 15 cc. of cold water. Stir with a short glass rod and when cool slowly dilute NH_4OH till slightly alkaline. Transfer the solution to a cylinder or Nessler comparison tube and dilute to 50 cc. If stronger in color than the standard take an aliquot and dilute it to 50 cc. If comparison is made in common Nessler tubes place unknown in one and add of standard to other until the colors match. If comparison is made in a colorimeter set the length of column of unknown solution at some definite mark and adjust length of known until colors match. Calculate parts per million of nitrate N in dry soil.

In case the soil contains more than 15 p.p.m. of chloride (this only occurs in the case of alkali soils or soils which have received a special or peculiar treatment) it is necessary to remove the chloride. This is done by including a solution of Ag_2SO_4 (4 g. in 1000 cc.) in the 250 cc. of solution with which the soil is treated. A 10 cc. addition is sufficient to remove 50 p.p.m. of chloride.

EXAMPLE OF DATA AND CALCULATION INVOLVED

Data: Used a 50 g. sample. In moisture determination 50 g. sample lost 10 g. of water. Of filtrate, used 10 cc. and diluted it to 50 cc. before making comparison.

In comparison:

(a) Using hand Nessler tubes.
Took 50 cc. or all of unknown.
And 40 cc. of standard to match color.

Calculations:

The 50 cc. of unknown represented nitrogen in $\frac{10}{250+10} \times \frac{50-10}{1} = \frac{40}{26}$ gms. of dry soil. Each c.c. of standard color solution contains .000001 gm. of nitrogen as nitrate. Forty c.c. would contain .00004 gm of nitrogen as nitrate. This amount of nitrogen as nitrate is contained in $\frac{40}{26}$ gms. of dry soil. Therefore, parts per million would be $\frac{26}{40} \times .00004 \times 1$ million.

Tabulate the results as follows:

	1	2	3
Weight of moist soil			
Weight of water in moist soil in grams			
Weight of dry soil			
Total number of c.c. water used for extraction			
Total number of c.c. extract used for determination			
Grams of dry soil represented in aliquot			
c.c. of standard used to compare with unknown (all or in part)			
Grams of nitrogen as nitrate in 1 gram of dry soil			
Pounds of nitrogen as nitrate in 2 million pounds of dry soil			
Tons of manure which would have to be nitrified to suppl y the above amount of nitrogen as nitrate			

Practice No. 18

The Effect of Color on Soil Temperature and the Relation of Drainage to Soil Temperature.

Each student will observe the results of a single experiment. Transfer the data to the note book, draw the curves on suitable graph paper and answer the questions.

A. Effect of Color on Soil Temperature.

Arrange the data as follows:-

Time	Thermometer 1"above surface		Thermometer 1"below surface		Thermometer 2"below surface		Thermometer 4"below surface	
	Black soil O.F.	Gray soil O.F.						
6 A.M.								
7 A.M.								
8 A.M.								
etc.								
6 P.M.								

B. Relation of Drainage to Soil Temperature.

Arrange the data as follows:-

Weather Conditions	Time	Drained				Undrained			
		1" above sur-face	1" below sur-face	2" below sur-face	4" below sur-face	1" above sur-face	1" below sur-face	2" below sur-face	4" below surface
		O.F.	O.F.	O.F.	O.F.	O.F.	O.F.	O.F.	O.F.
	6 A.M.								
	7 A.M.								
	8 A.M.								
	etc.								
	6 P.M.								

1. Draw curves to show variations in temperature due to soil conditions supplied.

2. There are two reasons why a "wet" soil is a "cold" soil. What are they? (See page 241).

3. Which is more important in influencing the temperature rise of soil, texture or moisture?

4. Does the soil temperature vary at the same rate as the air temperature?

5. Draw a diagram showing the influence of North and South exposures upon soil temperature.

POT TESTS FOR DETERMINING THE FERTILIZER NEEDS OF SOILS. (TRUOG)

* *

Pot tests when properly conducted give reliable information regarding the fertilizer needs of soils. When thus conducted the results check with field tests. To insure reliable results it is absolutely necessary that the soil be properly collected and thoroughly mixed; the fertilizing materials be used in proper amounts and thoroughly mixed with the soil; the planting be done properly, uniformly, and with good seed; and the cultures watered and otherwise taken care of uniformly and regularly which means daily.

EQUIPMENT NECESSARY

Two gallon glazed earthenware pots costing about $ .34 apiece are the most satisfactory containers for most purposes. One gallon jars may be used but they are too shallow. Four gallon jars are very good but they are more expensive, require more soil and material and are more difficult to move about. Wooden boxes and unglazed flower pots may be used but they are porous and become contaminated after the first use, so that they should be permanently marked and the same container always used with the same treatment. It is important to have a drainage hole in the bottom of the containers to allow the drainage of an excess of water which may have been applied unintentionally or have gotten in otherwise. Jars may be specially ordered with a 3/4 inch drainage hole on the side, flush with the inside of the bottom. Holes may be made in jars by tapping gently with a hammer and sharp punch. This is most easily done on the bottom of the jar.

A glass greenhouse is of course the best place to carry on a pot test. The test may also be made at a window having a southerly exposure. The pots may also be placed in a hotbed or cold frame. If there is no danger of freezing they may be placed directly outside and protected from birds and other animals with wire netting.

FERTILIZING MATERIALS

Commercial acid phosphate, muriate of potash, nitrate of soda and ground limestone may be used. To avoid possible chance of contamination it is safer to use pure salts in place of the commercial forms of the first three. It is also preferable to use monosodium phosphate in place of monocalcium phosphate because the former is more soluble and does not carry calcium which might confuse the test in regard to lime. The amounts of fertilizing materials later indicated are for a two gallon jar which has a diameter of 8¼ inches and an area of 53.4 square inches. A gram of fertilizer to a jar is equivalent to approximately 300 lbs. (exactly 286 lbs.) per acre. If containers of different area are used the amounts should be calculated accordingly.

The best materials to use are:
C. P. Potassium chloride - KCl containing 63% K_2O
C. P. Sodium nitrate - $NaNO_3$ containing 16.5% N.
C. P. Monosodium phosphate - $NaH_2PO_4 H_2O$ containing 51.5% P_2O_5
Good grade ground limestone - consisting usually of a mixture of $CaCO_3$ and $MgCO_3$ and containing the equivalent of 95 to 105% of $CaCO_3$

It is best to make a separate stock solution of each of the first three by dissolving in each case 100 g. of the salt and diluting to one liter. This will give enough stock solution in each case for 100 treatments. If only a few tests are to be made the amount of stock solution should be cut down accordingly. The stock solutions should be thoroughly shaken. In each case 10 cc. of stock solution (1 g. of salt) is used. This is approximately equivalent to using per acre: 350 lbs. of commercial muriate of potash, 300 lbs. of commercial sodium nitrate and 900 lbs. of commercial acid phosphate assuming the followin g:

Commercial	muriate of potash	contains	48 - 52% K_2O
"	sodium nitrate	"	14 - 15.5% N
"	acid phosphate	"	16 - 20% P_2O_5

If commercial fertilizers are used in the pot test, use one gram each of the muriate and nitrate and three grams of the phosphate. The limestone should be used according to the degree of acidity as directed in Wis. Bul. 312. Seven grams per jar is equivalent to one ton per acre.

PLAN OF THE TEST

If a complete test is to be conducted the treatments in the following series should be included.

1. Check, no fertilizer.
2. Phosphorus.
3. Potassium.
4. Nitrogen.
5. Phosphorus, potassium.
6. Phosphorus, nitrogen.
7. Potassium, nitrogen.
8. Phosphorus, potassium, nitrogen.

If the soil is acid repeat the series just given using lime in each case. The ideal plan is to run the whole in duplicate. If this is not practicable, at least the check should be in duplicate. If a legume is grown as the test crop the nitrogen treatments may be eliminated but the cultures should be inoculated. This will, however, not give information regarding the nitrogen needs of a non-legume on this soil. Alfalfa and medium red clover are ideal plants to test the lime needs of a soil; but corn and small grain cannot be used for this purpose.

In many cases a soil is known to contain sufficient nitrogen in which case the nitrogen treatment may be omitted. In some cases only the lime needs of a soil are tested. It is usually better, however, to include the others because often soils show an unsuspected need of certain elements.

CONDUCTING THE TEST

After the soil has been collected it should be thoroughly pulverized by breaking up the lumps and mixed by shoveling over several times. It is also a good plan to pass it through a quarter inch siev to remove stones, large roots and trash. If the soil is too wet for mixing, it should first be spread out and dried. After mixing and sieving, the soil is potted. The pots should first be numbered and weighed and the weights properly recorded. The pots are then filled to within one half inch of the top. The soil should be firmly packed in the pots just like it is in a good firm seed bed. The same weight of soil should be placed in each pot. At the time of potting a sample of soil should be taken for a moisture determination.

The next step is to apply the fertilizers. Lime is applied first and mixed with the soil by first emptying the pot and spreading the so on a tray or table and then sprinkling the lime over this and mixing with the hands. If commercial fertilizers are used for the various elements, they should be applied and mixed at the same time and in the same way as the lime. If pure salts are used in place of commercial fertilizers, they are dissolved as previously directed and applied in solution. To do this 10 cc. of the required stock solutions for each pot are all added to a quart of water and mixed and this is poured over the soil. If the pot is smaller than a 2 gallon one the amount of water should be decreased accordingly.

If the fertilizing elements are applied in solution it is more convenient to plant the seed before applying the solution, because it eliminates the necessity of working the soil when very wet, which is disagreeable and may puddle the soil.

Of clovers and alfalfa, about 50 seeds should be planted uniforml over the area at a depth of about ¼ inch. The best way to do this is to remove ¼ inch of soil, scatter the seed and replace the soil. When well started the cultures are thinned to 15 of the most vigorous plan uniformly distributed. The small grains may be planted in the same way as just described except that the depth is increased to about one inch. About 25 seeds should be planted and later thinned to 15. Corn should be planted about 2 inches deep. The corn seed should all come from the same ear and about 5 kernels should be planted in the center portion of the jar, leaving a space of several inches between the kernels. The corn is later thinned to three plants. Other crops are planted and thinned accordingly.

After the seed is planted the solution of fertilizer salts are applied unless previously mixed with the soil. In pouring these onto the pot a watch glass or piece of glass should be laid on the soil and the solution poured onto this to prevent washing out of the seed. A piece of porous wood should not be used for this. The pots should now be watered to standard weight or optimum water content which for different classes of soils is as follows:

Sands	10 - 15%
Sandy loams	15 - 20%
Silt loams	25 - 30%
Clays	30 - 35%
Peats	200 - 300%

The finer the texture and the higher the organic matter content the more water should the soil receive. Using this as a guide the experimenter must judge as to the exact moisture content to be maintained. Either distilled water, rainwater or snow water should be used in all cases.

CARE OF THE CULTURES

The cultures should be looked after daily. After the plants are growing rapidly they should be watered daily. It is best to apply the water in the evening with a sprinkler allowing it to thoroughly wash and wet the plants. This wetting of the plants washes off dust and helps to control insect pests. After a little experience a person can judge by appearance of the soil whether or not sufficient water is applied. It is well, however, to weigh a pot occasionally so as to check up the watering. Often the upper portion of the soil appears sufficiently wet while the lower portion is much too dry. If the pot has a drainage hole the condition of the soil at the bottom may be observed. The soil in the jar should be cultivated occasionally to prevent it from cracking away from the jar, and all weeds should be pulled out.

OBSERVING RESULTS

The effects of fertilizers are often apparent a few days after the plants are up. Notes should be recorded once a week or at some other regular interval. Pictures make a splendid record. In taking pictures the pots should be neatly arranged and labeled. Sometimes the effect of a treatment is hardly noticeable with the naked eye and yet a 25% increase has been produced. To show this it is necessary to harvest the crop. The legumes and small grains may be grown to maturity or cut at the hay stage. Corn is best cut when it reaches a height of 2 or 3 feet. This is done by cutting the crop and placing the harvest of each pot in a separate paper bag which has the same number as the pot. The untied bags are then placed in a room to air dry to constant weight. This may be hastened by placing them in an oven which does not heat to over 100° C. If dried at too high a temperature or too long at even a lower temperature, there will be a loss of other material than water. After the weight is practically constant, the dry material is emptied onto a sheet of paper and then placed on a scale and weighed.

The test from beginning to end should be recorded in a note book. The data is convenientl y kept in tabular form.

The results should be carefully interpreted in connection with the previous history of the field, yields secured, fertilizers and manure applied, chemical data available, and physical conditions like character of subsoil in relation to drainage and droughtiness.

PROBLEMS

A Comparative Study of Fertility Balances Based on Different Types of Farming (Michigan)

FERTILITY REMOVED FROM A SOIL BY ONE ROTATION.

Crops	Amount	P	K	Ca	N
Wheat	50 bu.	12 lbs.	13 lbs.	1 lb.	71 lbs.
Wheat straw	2½-tons	4	45	9.5	25
Corn	100 bu.	17	19	1.3	100
Corn stover	3 tons	6	52	21	48
Oats	100 bu.	71	16	2	66
Oat straw	2½ tons	5	52	15	31
Clover seed	4 bu.	2	3	5	7
Clover hay	4 tons	20	120	117	160

On a farm are rotations of corn, oats, wheat and clover. The average yields for one year are: corn, 50 bu. of grain, and 3000# of stover. Oats 60 bu. of grain, and 3000# of straw. Wheat, 20 bu. of grain and 2000# of straw. Clover, 3 tons of hay, and 2 bu. of seed. The grain, straw, and stover are removed from the soil in the oats, wheat and corn rotations. For the clover there are two clippings. The first 1½ tons of hay are removed. The second cutting is for seed, 2 bu. of seed are removed, and the straw (1½ tons) returned to the land. Granting that 2/3 of N in clover is in the top and that 2/3 of the N used by the plant comes from the air, how much fertility is removed from the soil by each crop and by the entire rotation?

What could be the cost of returning to the soil the P and K for the rotation, using acid phosphate at $26 per ton, and potash at $45 per ton? Acid phosphate contains 9.9% of P and potash contains 43% of K.

DAIRY FARM

20 cows - 5 horses - 10 cattle - 20 hogs

Crop produced	Plant food in produce: Nitrogen	Phosphoric acid	Potash	Produce	Consumed by Stock: Nitrogen	Phosphoric acid	Potash
Hay 10A-20T	*800	201.5	720.0	20 T			
Corn - 10 A.							
Grain 400 bu.	371.2	146.56	88.0	250 bu.			
Stover 12 T.	240.0	73.28	336.0	7.5 T.			
Corn 10 A.							
Silage 100 T.	680.0	229.00	880.0	100 T.			
Oats - 20 A.				800 bu			
Grain 1200 bu	768.0	318.77	230.4	Fed 6.5			
Straw 30 T.	384.0	120.91	748.8	Bed17.5			
Barley-10 A.							
Grain 340 bu.	285.6	124.57	81.6	340 bu.			
Straw 11 T.	132.0	43.51	242.0				
Beans - 10 A.							
Grain 200 bu.	480.0	146.56	156.19				
Straw 8 T.	208.0	47.63	304.00				
Pasture 30 A.	1718.1	480.9	1431.75				
Purchased							
Bran 7.5 T.				7.5 T.	327.5	439.74	240.0
Total removed from soil	5266.9	1933.19	5218.74				
Taken from the air*							

	Nitrogen	Phosphoric acid	Potash
Plant food in feed consumed by stock			
Loss during digestion			
Loss in handling manure			
Returned to soil in manure			
Plant food in pasture grass			
Loss during digestion			
Returned to soil			
Returned to soil in bedding, stover, etc.			
Total returned to soil			
Removed from soil in crops			
Total annual loss from soil			

Crops produced Produce	Sold from farm: Nitrogen lbs.	Phosphoric acid lbs.	Potash lbs.	Produce	Returned to soil: Nitrogen lbs.	Phosphoric acid. lbs.	Potash lbs.
Total returned to soil							
Total loss per 100 acres							

	Per cent N	P_2O_5	K_2O
Loss during digestion	34.3	37.5	20.4
Loss in handling manure	30	15	20

GENERAL FARM

Carrying 6 cows - 14 hogs - 4 cattle - 5 horses

Crops produced	Plant food in produce: Nitrogen	Phosphoric acid	Potash	Produce	Consumed by stock: Nitrogen	Phosphoric acid	Potash
Hay 10A - 20T	800*	201.5	720.0	17 T.			
Corn 15 A.							
Grain 600 bu.	556.8	219.87	132.0	287 bu			
Stover 18.1 T.	362.0	110.53	505.4	11.3 T.			
Oats 15 A A.				800 bu			
Grain 900 bu.	576.0	239.11	172.8	Fed 8 T			
Straw 23.5 T.	288.0	90.70	561.6	Bed 8 T			
Total consumed by stock							
Barley 10 A.							
Grain 340 bu.	285.6	124.6	81.6				
Straw 11 T.	132.0	43.51	242.0				
Wheat 15 A.							
Grain 375 bu.	450.0	192.00	90.0				
Straw 18.6 T.	186.0	56.54	222.6				
Beans 15 A.							
Grain 300 bu.	720.0	218.87	234.28				
Straw 12 T.	312.0	71.46	456.00				
Potatoes 5 A.							
1000 bu.	210.0	90.0	300.0				
Pasture 15 A.	859.05	240.48	715.88				
Total removed from soil	4937.45	1900.17	4434.16				

* Taken from the air

	Nitrogen	Phosphoric Acid	Potash
Plant food in feeds consumed by stock			
Lost during digestion			
Lost during handling of manure			
Returned to soil			
Plant food in pasture grass			
Loss due to digestion of pasture grass.			
Returned tosoil.			
Returned to soil in bedding, stover, etc.			
Total returned to soil			
Total removed from soil			
Total loss from soil			

GENERAL FARM 2.

Sold from farm				Returned to soil			
Produce	Nitrogen	Phosphoric Acid	Potash	Produce	Nitrogen	Phosphoric Acid	Potash
3 T.							
313 bu.				6.8 T.			
100 bu. 6.5 T.				8 T.			
340 bu. 11 T.							
375 bu. 18.6 T.							
300 bu.				12 T.			
1000 bu							

Total — Total

Per cent

	N	P_2O_5	K_2O
Loss during digestion	27.3	34.3	16.7
Loss in handling manure	45	25	40

Experiment

Plant food balance on a 100 acre Grain Farm, carrying 2 cows, 14 hogs, 5 horses.

Crops produced	Plant food elements in produce: Nitrogen Lbs.	Phosphoric acid Lbs.	Potash Lbs.	Consumed by stock: Produce	Nitrogen Lbs.	Phosphoric acid Lbs.	Potash Lbs.
Hay, 10 A. 20 T.	800.0*	201.5	720.0	12.5 T.			
Corn, 15 acres							
Grain, 600 bu.	556.8	219.87	132.0	45 bu.			
Stover, 18.1 T.	362.0	110.53	505.4	3 T.			
Oats, 20 acres							
Grain, 1200 bu.	768.0	318.81	230.4	613 bu			
Straw, 30 T.	384.0	120.93	748.8	Fed. 5 T.			
				Bed. 5.5 T			
Total consumed by stock							
Wheat, 25 A.							
Grain, 625 bu.	750.0	320.00	150.0				
Straw, 31 T.	310.0	94.24	371.0				
Beans, 15 A.							
Grain, 300 bu.	720.0	219.87	234.28				
Straw, 12 T.	312.0	71.46	456.00				
Potatoes, 5 A							
1,000 bu.	210.0	90.0	300.0				
Pasture, 10 A.	572.7	160.32	477.25				
Total removed from soil	4945.5	1927.53	4325.13				

	Per cent N	Per cent P_2O_5	Per cent K_2O
Loss during digestion	20.5	28.8	12.8

Sold from farm: Produce	Nitrogen Lbs.	Phosphoric acid Lbs.	Potash Lbs.	Returned to soil: Produce	Nitrogen Lbs.	Phosphoric acid. Lbs.	Potash Lbs.

	Nitrogen	Phosphoric Acid	Potash
Plant food in feeds consumed by stock			
Lost during digestion			
Loss during handling of manure			
Returned to soil			
Plant food in pasture grass			
Loss due to digestion of pasture grass			
Returned to soil			
Returned to soil in bedding, stover, etc.			
Total returned to soil			
Total removed from soil			
Total loss from soil			

SCORE CARD FOR JUDGING SOILS

General Farming with Dairying as Leader.

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	Perfect score	Student score	Corrected score
1.---Drainage; ______________ 20 points			
(a) Land having good artificial drainage and good slope giving good natural drainage - - - - - - - - - - - - - - - - - -	12		
(b) The absence of an impervious subsoil or hardpan - - - - - - - - - - - -	8		
2.---Workability; ______________ 10 points			
(a) Soil having good texture - - - - - - -	8		
(b) Soil having good tilth - - - - - - - - -	2		
3.---Water-holding; ______________ 40 points			
(a) Subsoil to at least 8 ft. not gravelly or "open, but of firm texture, favoring capillary rise of water - -	20		
(b) Soil having a fine texture - - - - - -	12		
(c) Soil well supplied with organic matter - - - - - - - - - - - - - - - - - -	8		
4.---Chemical composition ______ 30 points			
(a) Phosphoric acid (total amount)- - - (From 0.00 to 0.20 percent)	10		
(b) Lime carbonate (total amount)- - - -	8		
(c) Nitrogen (total amount) - - - - - - - (From 0.00 to 0.25 percent)	8		
(d) Potash (total amount) - - - - - - - (From 0.00 to 2.50 percent) - - -	4		
TOTAL	100		

Reduce from Total score for-

Erosion - from 0 to 40 points

Stones, stumps, gullies - from 0 to 30 points

Soil "exhaustion" - from 0 to 10 points.