THE GENESIS AND MORPHOLOGY OF THREE SOUTHWEST VIRGINIA SOILS WHICH WERE DEVELOPED FROM MATERIAL WEATHERED FROM LIMESTONE

by

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The writer wishes to express his appreciation to Dr. S. S. Obenshain under whose supervision this investigation was carried on. Also thanks are due [illegible] for his help in the sampling of the soil profiles and the parent rock.

INTRODUCTION

The soils of southwest Virginia are derived from material weathered from sedimentary rocks composed of limestones, shales, sandstones, or a combination of two or more of these rocks. From an agricultural viewpoint the soils derived from the material weathered from limestones are the most important. It is on these limestone soils that the majority of the commercial agricultural products are grown.

During the past six years practically the full time of the soil survey personnel of the Virginia Agricultural Experiment Station with their cooperative agencies has been devoted to the mapping of the soils in eight soughwest Virginia counties, which fall within the Limestone Valley and Upland Region. Practically no laboratory work, which would help in the understanding and aid in the evaluation of these soils, has been carried on in connection with these field studies.

The purpose of this investigation is to make a study of the genetical and morphological characteristics of certain of these soils which are underlain by limestone, with the hope that the data gathered will aid in the evaluation of field observations.

A REVIEW OF LITERATURE

Soil science has only recently been recognized as an independent branch of natural science. Formerly it was considered as a branch of agriculture which is an applied science. The ancient husbandman found that in some places the earth varied in its crop-producing power, and the early classifications were based on crop adaptations. The first attempt, according to de Sigmond (18), to liberate soil science from this position was made by a German geologist, Fallou. By basing his classification on geological-petrographic principles he unconsciously subordinated pedology to geology. It became evident that the variations in soil types could not be satisfactorily explained either by geological or petrographic origins, and as a result the modern concept of soil science, which considers the soil as a natural and independent body, began.

The study of soils under this new scientific approach, according to Joffee (9), was instigated by Ruprecht, a Russian soil scientist, (1866), and was later developed by Dokuchaiev and his pupils. Tulaikoff (19) states that the first problem of the soil scientist is to determine the factors of soil formation. This approach explains the most important properties of soil. After the factors of soil formation have been determined, there follows a more detailed study of the dynamics of the processes involved. This detailed study shows how the factors which are responsible for the development of soils are reflected in their character. When this interaction between soils and the factors of their formation is thoroughly understood, the investigator will know that under certain physiographic conditions and with a certain material weathered from a particular type of rock, certain soils may be expected.

Out of this scientific approach came the idea of studying soil profile which at this time was called, by Tumin "a body with a genetic complex of horizons formed in the process of humification and humus fixation". Joffee (9) states that the soil profile, a cross section of the earth's crust from the surface down to parent rock, has a certain morphological type which imparts specific characteristics to the constitution and construction of each horizon and that each type has a constant orderly system of relationships within the profile between horizons.

The study of the soil profile as a basis for soil classification was carried on in Russia many years before being introduced into the United States. Through the pioneer work of Marbut, this type of study was promulgated in the United States. According to Joffee (9) the first survey in the United States in which the soil profile was described was made in 1921. With the introduction of the soil profile as a basis of study in the United States, numerous investigations have made extensive studies of the genetical and morphological characteristics of the various soil types of the United States. Wheeting (20) reports that in to make a thorough study of a profile the ten following factors must be considered: (1). the number of horizons, (2). the color of the horizons, (3). the texture of the horizons, (4) the structure of the horizons, (5). the arrangement of the horizons, (6). the chemical composition of the horizons, (7). the thickness of the horizons, (8), the thickness of the true soil, (9) the character of the soil material,(10). the geology of the parent material. McCool, Veatch and Spurway, (13), in studying the soils of Michigan, report that the primary purpose of their study was to ascertain whether chemical and physical constitutional differences exist between separate members of horizons of the soil and to what extent the visible phenomena in the field can be correlated with laboratory data. Shaw (17) made a field study of the soils of California in which several stages of development from youth to maturity were found. He demonstrated with different soil types the persistent influences of parent material and the modifications due to the variations in climate and vegetative cover. Cobb (5), by analyzing the residual soils and the parent rock, showed the amounts of material lost during the weathering of basic and acidic rocks. Marbut (12), by chemical and physical studies of the profile, showed the genetical and morphological relationships existing between the soils of the great soil groups of the United States and also the differences found in the profile development of the soils occurring within the same great soil group.

According to Marbut's (12), classification, the soils of eastern United States belong in one category or order known as the Pedalfers. Within this order there are three suborders, namely; Podzols, Gray-Brown Podzols, and Red and Yellow soils. The Podzols occur in the northeastern part of the region and the Red and Yellow soils in the southeastern part of the region. The Gray-Brown Podzols are found in the north central portion of this region just below the Podzols.

Within the Gray-Brown Podzolic group there is a vast area of soils underlain by limestone. Two soil series commonly found in this area, according to the United States Bureau of Soils (3 & 4), are Hagerstown and Clarksville. The Hagerstown, which is an extensive limestone valley soil, occurs throughout the valleys of the Appalachian Mountain region and the Bluegrass region of Kentucky. The Clarksville is another extensive upland limestone valley soil occurring in practically the same area as the Hagerstown and is underlain by a cherty dolomitic limestone.

Merrill (14), in his study of the weathering calcareous rocks, found that the chemical agencies of weathering predominated over those that were purely physical. After studying the amounts of materials lost through weathering he concluded that little or no silica was lost in the decomposition of fresh carbonate rock. Marbut (12), points out that the residue from limestone decomposition may have a higher percent of iron and alumina when first formed than at any other subsequent time. He also showed by the use of the molecular ratios of silica (SiO_2) to alumina (Al_2O_3), silica (SiO_2) to iron (Fe_2O_3), and bases (Ca, Na, and K) to alumina (Al_2O_3), that in general the Gray-Brown Podzols have a movement of the sesquioxides from the A to the B horizon. Recently, Rogers (13) in studying the physio-chemical relationships of some of the Piedmont soils used the same ratios as used by Marbut to point out the fact that the slow transition of the sesquioxides to the lower horizon in some of these soils was due to the high percent of bases present.

More recent work by Alexander, Byers and Eddington (1), on soils derived from the residual material left by solution and decomposition of limestone, showed by mechanical analysis that the parent materials or C horizons of all the soil profiles studied were clays. The chemical analyses showed a higher percent of silica in the A_2 horizon than in the B_2 horizon in every case. This phenomenon is evidence of podzolization. There was a smaller amount of silica in the C horizon than in the A_2 horizon. These same authors pointed out that iron and aluminum oxides had been leached from the A horizons and that in only four out of ten cases were the B horizons as high in iron and aluminum oxides as the horizon beneath. Although all the soils studies were derivatives of limestone, the calcium oxide content ranged from a mere trace to a relatively high amount. Three representative samples of the Hagerstown series were included in this study and they were found to vary in chemical composition to quite a noticeable degree, the difference being attributed to variations in parent material, relief and climate.

A mineralogical and chemical study of the characteristics of a Hagerstown profile made by Jeffries and White (8), showed that, upon the weathering of the primary silicates, secondary alumino-silicates were formed which tied up the alumina in an insoluble form thus preventing it from being removed from the soil. They also pointed out that the free iron oxide removed from the soil increased considerably with depth of profile.

Robinson (15) states that soils derived from hard limestone tend to have a reddish or reddish brown color and contain free sesquioxides in the weathering complex due to the leaching of the bases which brings about desilification. He further states that the Hagerstown series which belong to the red and brown soils has had the calcium carbonate entirely leached from the profile.

de Sigmond (18), and MacIntire et. al (11), state that in certain horizons, magnesium oxide accumulates at the cost of calcium oxide and that in calcareous soils calcium oxide is leached out of the upper horizons on a larger scale than magnesium oxide.

MATERIALS AND METHODS

Materials

The profile samples investigated were taken in the fall of 1937 at the conclusion of the soil survey of Russell County, Virginia, by H. C. Porter of the Virginia Agricultural Experiment Station and R. C. Jurney of the U. S. D. A., Bureau of Plant Industry. The parent rock samples were taken by the investigator in the fall of 1940. One sample of rock was taken for each corresponding soil type.

Three soil types, all occurring within the Gray-Brown Podzolic region, were investigated. These three soil types were Hagerstown silt loam, Pisgah silt loam and Clarksville cherty silt loam.

The Hagerstown profile sample (Figures 1 and 2) was taken in a clover field in Russell County, Virginia, one mile east of Lebanon. It was underlain by a dolomitic limestone known as the Maryville limestone (Figure 3), belonging to the Honaker formation (21), and was typically found on slopes of 2 1/2 to 7 1/2 percent, although it did occur on slopes above 15 percent. It was comparatively erosive and generally stony on the steeper slopes. The parent rock occupies a valley position and as a result the soils are among those that occupy the lowest upland position in the county.

The Pisgah silt loam (Figure 4) profile sample was taken in Russell County, three-fourths of a mile south of Hansonville, Virginia. It is underlain by a highly calcareous limestone (Figure 5), belonging to the Lenoir formation (21) which in places contained a small amount of black chert. Both internal and external drainage are good and, as a result, erosion was not noticeable on slopes below 15 percent. This particular sample was taken in the transitional zone between a typical Pisgah profile and one of the red soils. Therefore, the sample had a slightly reddish color which was not typical of the Pisgah silt loam. With the Hagerstown series, it occupied the lowest upland positions in the county.

The Clarksville cherty silt loam sample (Figure 6), was taken in Russell County one mile northeast of Hansonville, Virginia, in virgin new ground. It is underlain by a dolomitic limestone (Figure 7), known as the Nitteny dolomite, which is a member of the Copper Ridge formation (21) and it contains a considerable quantity of chert. In places chert comprised 35 to 40 percent of the soil mass. It occurred on the steeper slopes and ridges of the inter-valley sections of the county. Its drainage was good and it did not erode very easily.

The following are profile descriptions of the three soils investigated:

Hagerstown Silt Loam

A_1 0-6" Grayish-brown to dark brown friable silt loam with a rather high organic matter content.

A_2 6-10" Yellowish-brown friable silty clay loam, slightly heavier than the layer above.

B_1 10-34" Slightly reddish-brown friable silty clay, containing a few mineral concretions.

B_2 34-42" Reddish-Brown silty clay, firm, plastic and heavy, containing numerous mineral concretions.

C 42-47" Reddish-brown friable silty clay mingled with spots of yellow, containing numerous mineral concretions.

D Parent Rock. A bluish-gray soft to medium hard fragmental limestone which is coated with light gray to brownish material on the breakage planes. It breaks up easily into angular fragments ranging in size from 1/4 to 2 inches in diameter.

Pisgah Silt Loam

A 0-8" Brown friable mellow heavy silt loam with a large amount of organic matter.

B 8-38" Slightly yellowish-brown friable silty clay loam which crumbles into a fine granular mass. Numerous mineral concretions are present in this layer.

C 38-45" Light yellowish-brown silty clay loam mingled with yellow and gray in spots. Small pieces of chert are found in this layer.

D Parent Rock. Steel gray, hard, high-grade limestone which carries streaks of white material (probably Calcite), and nodules of black chert in places.

Clarksville Cherty Silt Loam

A_1 0-2" Dark grayish-brown silt loam containing a large quantity of organic matter.

Figure 1. A Profile of Hagerstown Silt Loam with an Outcrop of Maryville Limestone one mile northeast of Lebanon, Virginia along U. S. Route No. 19.

Figure 2. A Profile of Hagerstown Silt Loam one mile northeast of Lebanon, Virginia along U. S. Route No. 19. Notice the uneven weathering of the parent rock.

Figure 3. Maryville limestone, a member of the Honaker formation. This picture was taken in a road cut one mile northeast of Lebanon, Virginia.

A_2 2-10" Light yellowish-brown to brownish-yellow, mellow, cherty silt loam.

B 10-37" Light yellowish-brown cherty silty clay loam which crumbles into a granular mass.

C_1 37-45" Yellow to rust brown silty clay with small to large angular chert fragments thoroughly mixed.

C_2 45-55" Yellow to reddish-yellow friable silty clay.

D Parent Rock. Olive gray medium hard rock with coatings of a yellowish powdered material, probably limonite. It breaks into angular fragments of varying sizes.

Methods.

In the field sampling of these soils, duplicate samples of each horizon and subhorizon were taken according to the procedure followed in the sampling of profiles by the Soil Survey Division of the Bureau of Plant Industry.

One set of the samples were sent to the U. S. D. A. Bureau of Plant Industry where mechanical analysis was made according to the standard pipette method.

The other set of samples was brought to Blacksburg where the chemical analyses were made by the investigator according to the methods described by the Association of Official Agricultural Chemists (2), with the exception of the magnesia determination which was made according to the method as described by Handy (7). The pH determinations were made by means of the glass electrode using 25 grams of soil to 50 cc of distilled

Figure 4. A Profile of Pisgah Silt Loam one mile south of Hansonville, Virginia along U. S. Route No. 19.

Figure 5. Lenoir limestone one mile south of Hansonville, Virginia. The parent rock of Pisgah Silt Loam.

Figure 6. A Profile of Clarksville Cherty Silt Loam one mile northeast of Hansonville, Virginia.

Figure 7. An outcrop of Nittany dolomite which is the parent rock of Clarksville Cherty Silt Loam. This picture was taken one mile northeast of Hansonville, Virginia.

water. Readings were made after the mixture had been thoroughly stirred and allowed to stand for 30 minutes.

DISCUSSION OF RESULTS

Mechanical Composition

The mechanical analyses of the soils investigated are given in Table 1, and are graphically represented in Figures 8, 9 and 10. The data show that both Pisgah silt loam and Clarksville cherty silt loam were high in silt, the surface horizons in each case being silt loams. The Hagerstown profile contained 38.7 percent clay in the surface horizon and would therefore be classed as a clay according to standards set up by Davis and Bennett (6). However, the field classification showed it as Hagerstown silt loam. The B horizons of the Hagerstown and Pisgah profiles with 65 and 60 percent clay respectively, were classified as clays, whereas the B horizon of the Clarksville profile with only 24 percent clay was classed as a silty clay loam. In other components the B horizons were quite variable with Hagerstown silt loam having 25 percent silt and 8 percent sand, the Pisgah silt loam having 41 percent silt and 28 percent sand, while the Clarksville cherty silt loam contained 55 percent silt and 21 percent sand.

The C horizons or parent materials of all the profiles studied were clays. The amount of clay ranged from a maximum of 75 percent in Hagerstown silt loam to 47 and 50 percent, respectively, for Pisgah silt loam and Clarksville cherty silt loam. The silt content of the parent material was quite variable, with Clarksville cherty silt loam containing approximately 45 percent, Pisgah silt loam 40 percent, and Hagerstown silt loam 19 percent.

Table 1. The Mechanical Analyses of Hagerstown Silt Loam, Pisgah Silt Loam and Clarksville Cherty Silt Loam.*

Horizon	Depth	Fine Gravel (diameter 2-1 mm.)	Coarse Sand (diameter 1-.5 mm.)	Medium Sand (diameter .5-.25 mm.)	Fine Sand (diameter .25-.1 mm.)	Very Fine Sand (diameter .1-.05 mm.)	Silt (diameter .05-.002 mm)	Clay (diameter -.002 mm.)	Total
				HAGERSTOWN SILT LOAM					
A_1	0-6"	1.0	1.8	2.9	6.5	4.5	44.6	38.7	100.0
A_2	6-10"	0.3	1.1	1.8	3.5	2.6	31.4	59.3	100.0
B_1	10-34"	0.5	0.9	1.6	3.1	2.2	30.5	61.2	100.0
B_2	34-42"	0.5	1.0	1.6	3.1	2.2	19.6	72.0	100.0
C	42-47"	0.2	0.6	0.9	1.9	2.1	19.3	75.0	100.0
				PISGAH SILT LOAM					
A	0-8"	2.2	4.0	3.7	6.6	4.2	61.3	18.0	100.0
B	8-38"	1.4	2.7	1.9	2.1	1.3	40.7	49.9	100.0
C	38-45"	2.4	3.6	2.2	2.7	2.0	39.7	47.4	100.0
				CLARKSVILLE CHERTY SILT LOAM					
A_1	0-2"	7.8	5.7	3.5	5.6	3.6	57.2	16.6	100.0
A_2	2-10"	3.1	4.6	3.3	5.6	3.7	62.0	17.7	100.0
B	10-37"	5.2	4.6	2.9	4.7	3.4	55.4	23.8	100.0
C_1	37-45"	1.9	3.3	2.7	4.7	3.7	51.6	32.1	100.0
C_2	45-55"	0.0	0.5	0.7	1.8	2.0	44.8	50.2	100.0

* U. S. D. A. Classification expressed in percent on the oven dry basis. Previous to January 1, 1938 .05 to .005 mm. in diameter was called silt, less than .005 mm. in diameter was called clay. These analyses were made December 22, 1939 in the laboratory of the U. S. D. A. Bureau of Plant Industry.

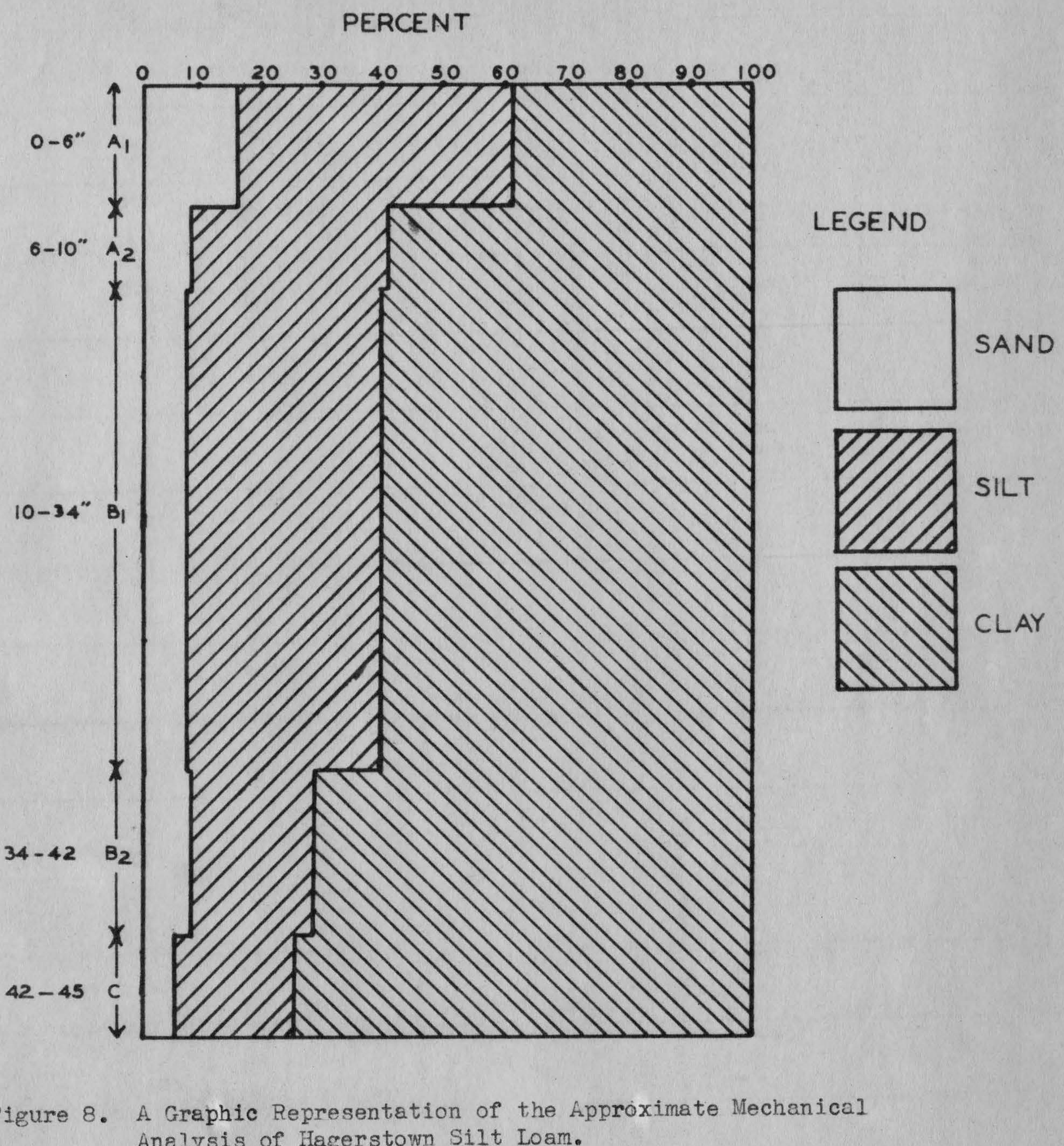

Figure 8. A Graphic Representation of the Approximate Mechanical Analysis of Hagerstown Silt Loam.

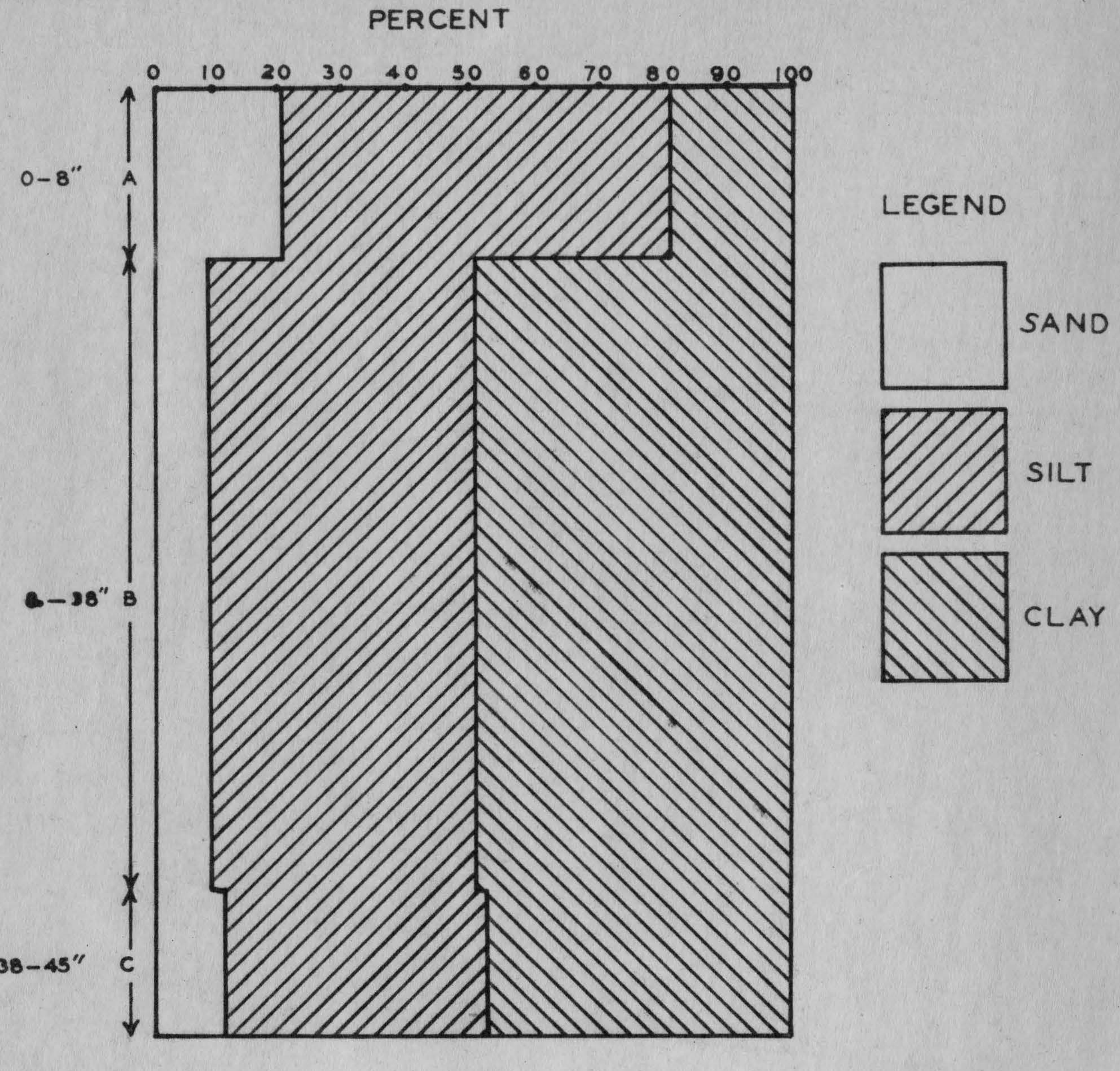

Figure 9. A Graphic Representation of the Approximate Mechanical Analysis of Pisgah Silt Loam.

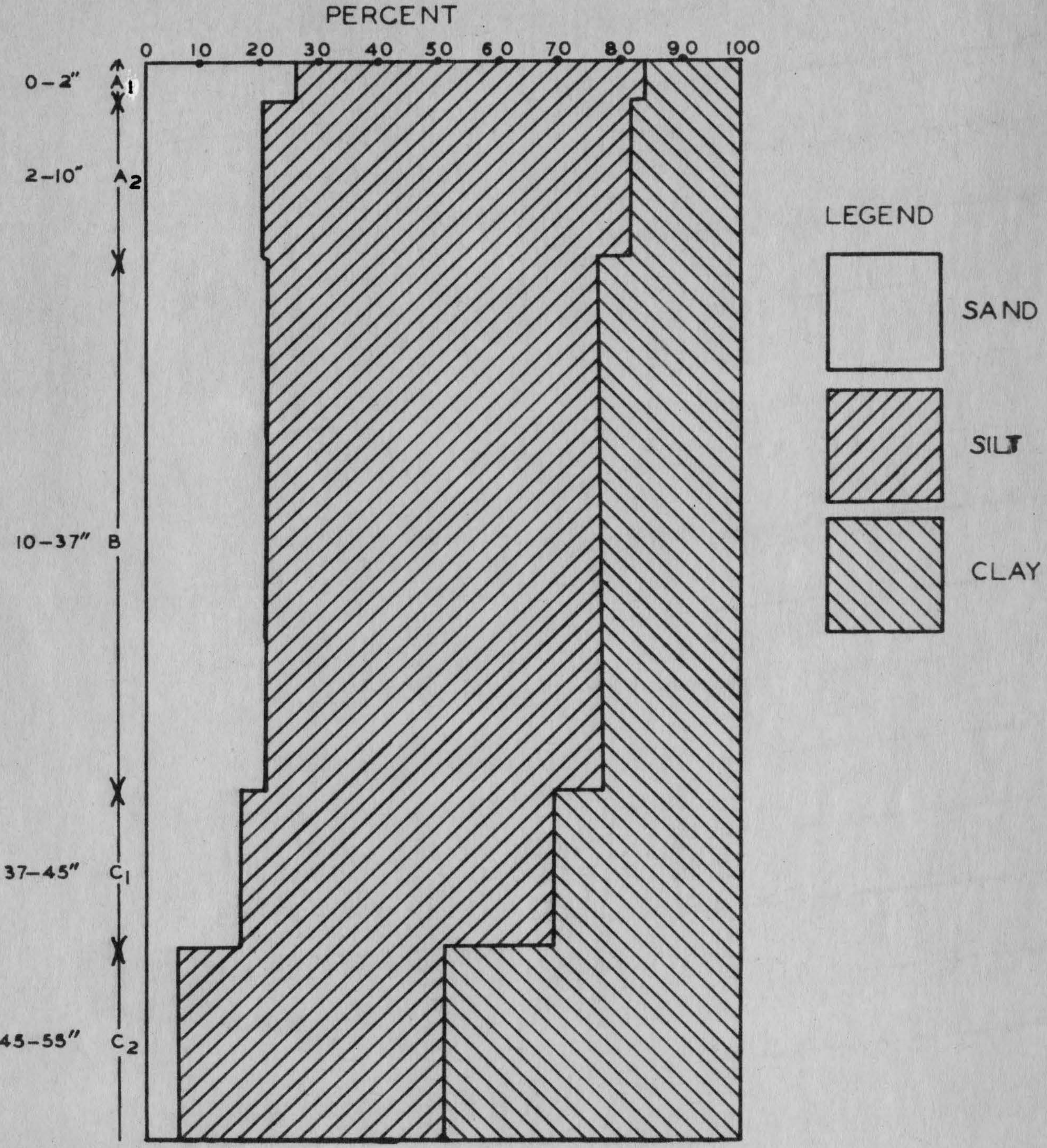

Figure 10. A Graphic Representation of the Approximate Mechanical Analysis of Clarksville Cherty Silt Loam.

The distinct break in the silt and clay content of the C_1 and C_2 horizons of the Clarksville profile was probably due to variations in parent rock. This viewpoint was supported by the fact that very little chert was found below the C_1 horizon. The content of sand in the C horizons did not run very high, the largest amount being in the Pisgah silt loam, 13 percent, and the smallest amount in the Clarksville cherty silt loam which had only 5.3 percent.

Chemical Composition

The chemical composition of the soils investigated is shown in Table 2, and graphically represented in Figures 11, 12 and 13. The A or A_2 horizon in every case was more silicious than the B horizon. This is evidence of the podzolic nature of the soil forming processes. Data by Alexander, Byers and Eddington (1) on some soils derived from material weathered from limestone show the same trend. The silica, being more resistant to weathering than the other components, was left behind while the other materials were moved down or leached out of the upper horizons. The C horizons contained a smaller content of silica than the A or A_2 horizons in every case, while the B horizons contained a higher content of silica than the C horizons.

The parent rocks or D horizons in all cases contained a very small content of silica as compared to the horizons which occurred above it. The Clarksville parent rock contained much more silica than that of the other soils studied. This fact is reflected in the higher silica content of the Clarksville profile.

The iron and alumina[1] have been leached from the A horizons, as indicated by the relatively small amounts found in the A horizons as compared with the amount found in the C horizons. These results were expected since the iron and alumina generally occurred in the clay complex. The B horizon of the Gray-Brown podzol, according to Marbut (12), is generally thought of as having an accumulation of iron and alumina. However, in two out of three cases studied, the B horizon was lower in iron and alumina content than the horizons beneath. As pointed out by Marbut (12), the residue from limestone decomposition may have a higher percent of iron and alumina when first formed than at any subsequent time. The parent rock contained a small amount of iron and alumina as compared with the overlying soil profile. The Clarksville parent rock contained the highest amount, 3.2 percent, with Hagerstown and Pisgah parent rock containing 1.45 and 1.37 percent, respectively.

Titanium determinations were not made in connection with this study. Alexander, Byers and Eddington (1), in working with limestone soils found the small amount of titanium present to be of no particular significance.

The content of magnesium oxide was fairly high in all the soils, with the exception of the Clarksville's A, B, C_1 horizons, which appeared to be quite thoroughly leached of this constituent. Hagerstown silt loam and Pisgah silt loam contained

1 Alumina as mentioned in this paper represents Al_2O_3 plus TiO_2.

approximately equal amounts of magnesium oxide. The C horizon in every case was slightly higher in magnesium oxide than the B horizon. The surface horizons in general had a higher magnesium oxide content, due to the presence of organic matter. The high content of magnesium oxide in Hagerstown silt loam and Pisgah silt loam appeared to be tied up with the clay complex, since in all horizons where the clay content was high the magnesium oxide content was also relatively high. The parent rock varied in magnesium oxide content, Hagerstown silt loam and Clarksville cherty silt loam having the highest, 22 and 19 percent respectively, and Pisgah silt loam having only 4 percent. From this it is concluded that the Hagerstown and Clarksville soils are derivatives of dolomitic limestone, while the Pisgah soil is a derivative of a relatively high grade limestone. All of these soils have been thoroughly leached of magnesium oxide, as shown by the analysis of the parent rock.

With the exception of the A_1 horizon in Clarksville cherty silt loam the quantities of calcium oxide in all horizons were small in comparison with the magnesium oxide content. de Sigmond (18), pointed out that in certain horizons magnesium oxide accumulates at the cost of calcium oxide, and that in calcareous soils, calcium oxide is leached out of the upper horizons on a larger scale than magnesium oxide. The entire profile in all cases was thoroughly leached of calcium oxide. In connection with this study, a sample of the C_2 horizon of the Hagerstown profile was taken in the fall of 1940 near the same place where the

Table 2. The Chemical Analyses of the Soil Profiles of Hagerstown Silt Loam, Pisgah Silt Loam, and Clarksville Cherty Silt Loam.*

						Expressed in Percent - Oven Dry Basis							
Horizon	Depth	SiO_2	R_2O_3*	Fe_2O_3	Al_2O_3**	MgO	CaO	P_2O_5	K_2O	O. M.	Ignition loss	Total	pH
						HAGERSTOWN SILT LOAM							
A_1	0-6"	59.25	28.60	9.67	18.64	.88	.31	.29	.99	3.71	9.04	99.07	5.95
A_2	6-10"	56.84	33.83	11.27	22.30	1.30	.34	.26	.88	1.63	7.98	101.17	5.60
B_1	10-34"	54.69	35.95	12.15	23.54	1.14	.30	.26	.98	1.07	7.72	100.78	5.70
B_2	34-42"	51.71	38.61	12.28	26.02	1.18	.29	.31	.95	.95	8.43	100.17	5.60
C	42-47"	47.73	41.52	12.70	28.47	1.30	.29	.35	.94	.84	9.12	100.90	5.55
D***	------	1.97	1.40	.54	.83	22.13	32.11	.03	.22	----	43.82	101.45	----
						PISGAH SILT LOAM							
A	0-8"	70.62	17.85	6.12	11.57	1.23	.40	.15	1.00	6.77	10.35	101.45	5.95
B	8-38"	68.78	25.71	8.41	17.16	1.13	.17	.14	.97	.78	5.22	101.98	4.65
C	38-45"	69.03	25.34	9.09	16.12	1.16	.14	.13	.92	.71	5.11	101.70	4.55
D	------	1.85	1.51	.24	1.21	3.77	46.27	.06	.23	----	44.07	97.50	----
						CLARKSVILLE CHERTY SILT LOAM							
A_1	0-2"	69.53	7.19	2.13	4.74	.60	1.23	.32	1.05	18.84	21.24	100.84	6.30
A_2	2-10"	89.50	7.50	2.48	4.92	.38	.20	.09	.98	1.54	2.63	101.19	5.25
B	10-37"	87.84	10.21	3.77	6.39	.55	.14	.05	.96	.33	1.89	101.59	4.90
C_1	37-45"	84.25	13.01	3.94	8.99	.84	.16	.07	.90	.29	2.27	101.43	4.85
C_2	45-55"	71.12	22.22	7.04	15.02	1.55	.13	.14	.87	.40	3.91	99.80	4.50
D	------	11.45	3.18	.49	2.67	19.20	28.54	.02	.21	----	40.02	102.41	----

* R_2O_3 equals to Fe_2O_3 plus Al_2O_3 plus P_2O_5.

** Al_2O_3 includes TiO_2.

*** D is the parent rock.

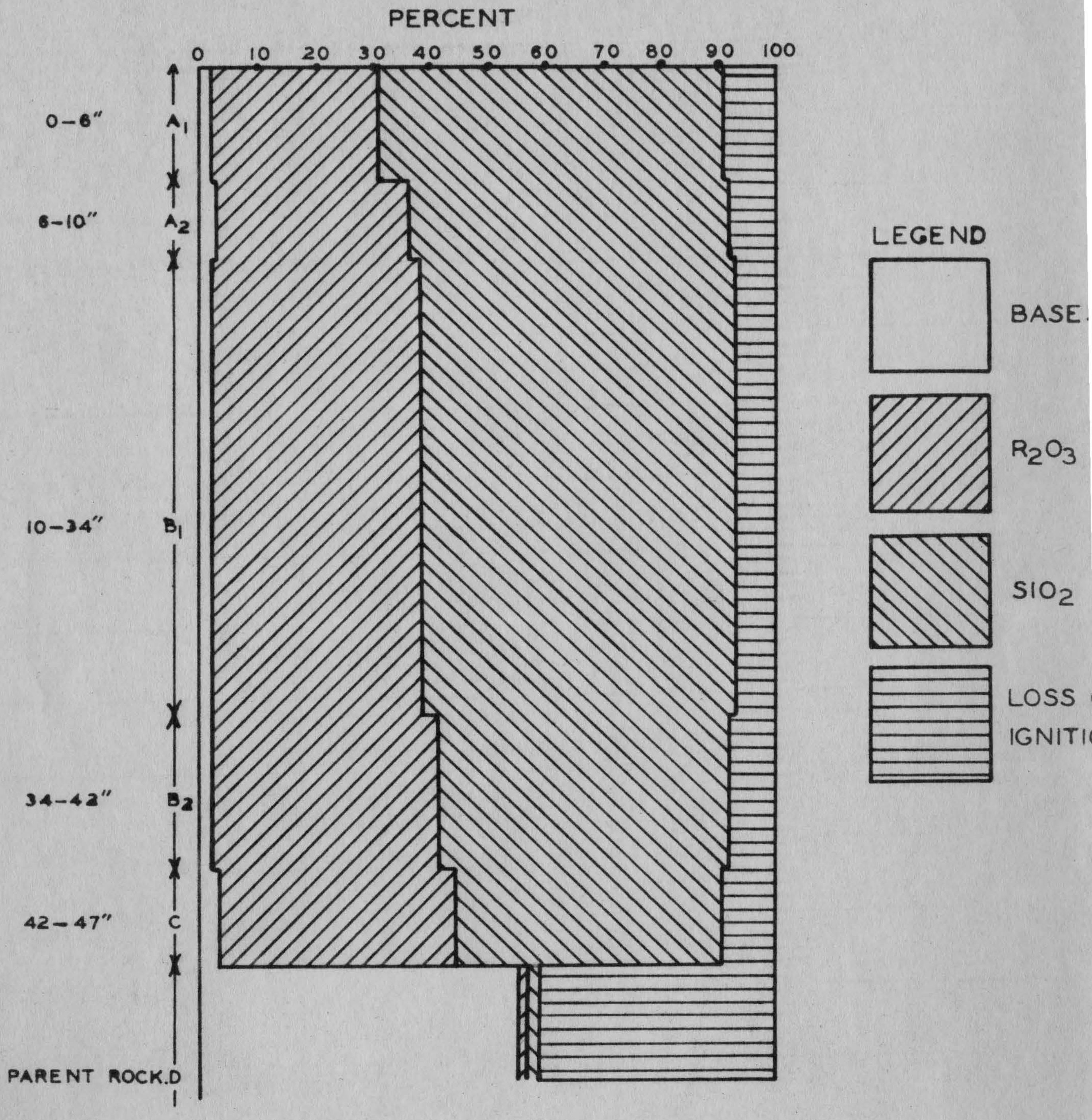

Figure 11. A Graphic Representation of the Approximate Chemical Analysis of Hagerstown Silt Loam.

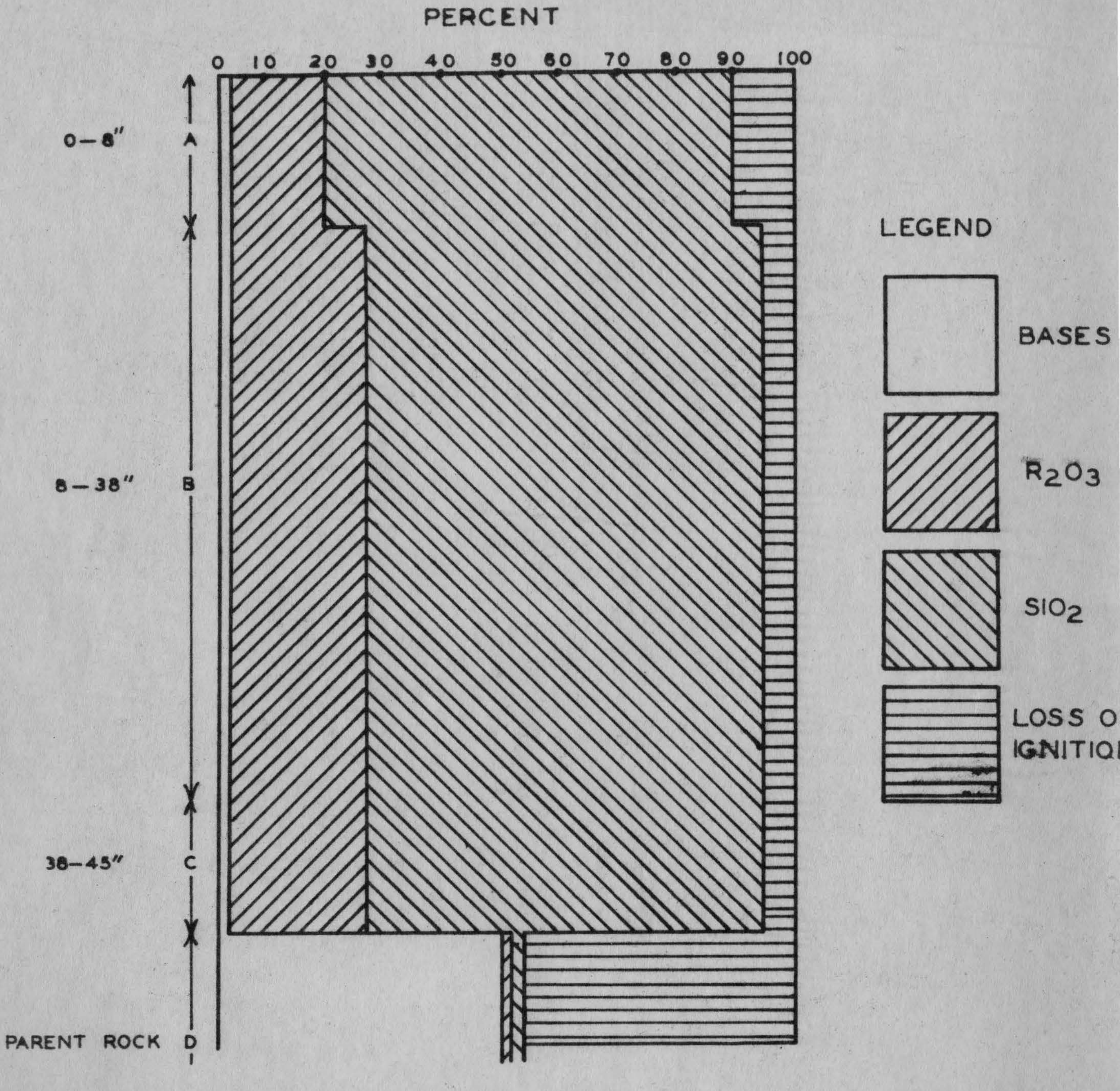

Figure 12. A Graphic Representation of the Approximate Chemical Analysis of Pisgah Silt Loam.

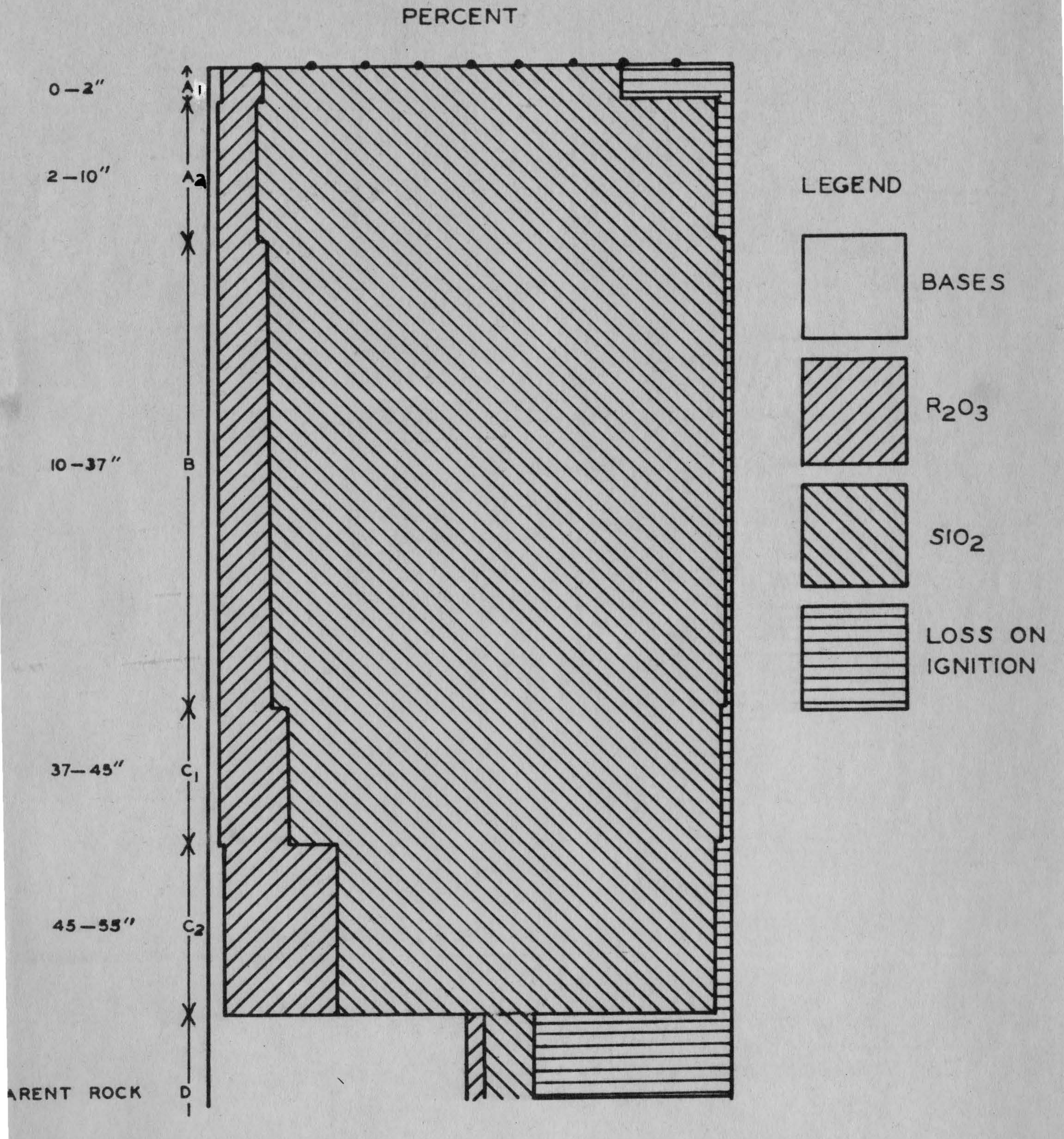

Figure 13. A Graphic Representation of the Approximate Chemical Analysis of Clarksville Cherty Silt Loam.

original sample was taken. This horizon was designated as the C_2 horizon because it was a layer of approximately 2 to 3 inches in thickness lying in contact with the parent rock. The reason for taking this sample was to ascertain whether or not there was an accumulative zone present in the Hagerstown soil. An analysis of this horizon showed a calcium oxide content of twice the amount of any other horizon occurring above it in the profile. This high calcium oxide content points out that this particular profile had been leached to within 2 inches of the parent rock, which was highly calcareous. Below the surface horizons, in which the organic content was relatively high, there was a decrease in the amount of calcium oxide with an increase in depth of profile. The parent rock contained a large amount of calcium oxide, Pisgah silt loam having the highest with a maximum of 46 percent and Hagerstown silt loam and Clarksville cherty silt loam having 32 and 28 percent respectively. The 46 percent calcium oxide content in the Pisgah parent rock is evidence for its being called a high grade limestone. The heavier soils contained the highest amount of calcium oxide, regardless of the calcium oxide content of the parent rock.

The phosphorus content of the surface horizons of these soils was relatively high, due to the presence of considerable quantities of organic matter. In the Hagerstown profile the A_1 horizon contained .29 percent P_2O_5. Below this depth there was a slight increase in the P_2O_5 content as the depth increased. The Clarksville and Pisgah profiles showed the opposite trend, except for the C_2 horizon of the Clarksville. As pointed out before, this distinct difference in the C_2 horizon was probably caused by rock variations. The high phosphorus content of the A_1 horizon of the Clarksville cherty silt loam was due to the high amount of organic matter present. Taking the profiles as a whole, the Hagerstown silt loam, which was the heaviest soil, contained the highest amount of phosphorus. The parent rock of the Hagerstown silt loam, Pisgah silt loam and Clarksville cherty silt loam contained .03, .06 and .02 percent of P_2O_5 respectively.

The potassium content of the three soils studied was approximately the same. All surface horizons contained a higher percent of potassium than the horizons beneath. The trend in all cases was a slight decrease in potassium as depth of soils increased. The parent rock of the three soils had practically the same content of potassium, not varying more than .02 percent potassium oxide in any case.

In all of the surface horizons, organic matter was relatively high. In the Hagerstown silt loam, which was the heaviest of the three soils, there appeared to be a slight infiltration of organic matter from the A_1 horizon down through the A_2 and into the B_1 horizon. In Pisgah silt loam and Clarksville cherty silt loam very little organic matter was found below the A horizon. The 0-2" layer or A_1 horizon of the Clarksville cherty silt loam contains 19 percent organic matter, while the horizon just beneath it contained only 1.5 percent, which was relatively low. The organic matter in Virgin soils is a good indicator of their fertility. From this standpoint, Pisgah silt loam with an organic matter content of approximately 7 percent in the A horizon was the most fertile soil of the three studied. Field observations confirm this fact. The productivity ratings of the three soils studied would be in the order of Pisgah silt loam, Hagerstown silt loam and Clarksville cherty silt loam.

The loss on ignition included the organic matter, the combined water, and the carbonates of the soil. A study of the combined water was not made in connection with this study. According to Alexander, Byers and Eddington (1), the combined water of the soil was found to be dependent upon the quantity and kind of colloid present in the soil. The high percent of ignition loss in the case of the parent rocks was due to the presence of large amounts of carbonate in the rock composition.

The pH determinations showed all the soils slight to medium acid in the top horizons, with an increase in acidity as the depth increased. In the data presented, none of the soils showed a carbonate layer, but as mentioned before in this study, a sample of the C_2 horizon of the Hagerstown profile was taken in 1940 and the pH of this horizon was 7.1 which may indicate the presence of a carbonate layer.

A better expression of the changes which have taken place in the horizons through the process of soil development was obtained by determining the molecular ratio of silica to alumina, silica to iron and bases to alumina after calculating the analyses to a mineral basis (free from all combustible and volatile matter). According to Marbut (12) the silica to alumina ratio shows two things: (1) The result of differential decomposition of the silicated minerals in the horizons, and (2) The shifting of alumina from the upper horizons and its accumulation in the lower horizons. Marbut (12) also states that the silica to iron ratio helps to explain the shifting of materials in the soil: and that the base to alumina helps measure the changes taking place in the transformation of decomposed or at least unconsolidated rock material to soil. The significance of the molecular equivalent as shown in Table 3 is the relationship of these figures for each constituent in the various horizons of the soil and not the interrelations of the constituents themselves (12).

The molecular ratios and the molecular equivalents of the three soils studied are presented in Table 3. The silica to alumina ratio is represented by the letters sa; the silica to iron ratio is represented by the letters sf; and the base to alumina ratio is represented by the letters ba.

The sa ratio in all of the A or A_2 horizons is slightly higher than that of the B horizons. The Clarksville with a ratio of 30.2 for the A horizon and 24.83 for the B horizon showed the most development. Marbut (12) states that the wider the sa ratio between the A_2 and the B, the more development has taken place. The B horizon of the Pisgah had a smaller ratio than the C horizon. This lower ratio in the B horizon of Pisgah may be, according to Marbut (12), due to either the greater loss of silica in the B than the A, or to an accumulation of the alumina in the B horizon through alluviation. The sa rationin the C horizon of the

Table 3. The Relative Molecular Equivalents and Ratios of Hagerstown Silt Loam, Pisgah Silt Loam, and Clarksville Cherty Silt Loam.*

Horizons		Molecular Equivalent Composition**			Molecular Ratios		
		SiO_2	Fe_2O_3	Al_2O_3	sa	sf	ba***
HAGERSTOWN SILT LOAM							
A_1	0-6"	1.08	.06	.20	5.40	18.00	.090
A_2	6-10"	1.03	.08	.24	4.29	12.87	.071
B_1	10-34"	.97	.08	.25	3.88	12.13	.068
B_2	34-42"	.94	.09	.28	3.36	10.44	.060
C	42-47"	.87	.09	.31	2.81	9.67	.055
D	P. R.	.058	.006	.015	3.87	9.67	68.26
PISGAH SILT LOAM							
A	0-8"	1.31	.04	.14	9.35	32.75	.143
B	8-38"	1.21	.06	.18	6.72	20.17	.077
C	38-45"	1.21	.06	.16	7.56	20.17	.081
D	P. R.	.055	.003	.021	2.61	18.33	70.67
CLARKSVILLE CHERTY SILT LOAM							
A_1	0-2"	1.47	.02	.06	24.50	73.50	.700
A_2	2-10"	1.51	.02	.05	30.20	75.50	.300
B	10-37"	1.49	.02	.06	24.83	74.50	.200
C_1	37-45"	1.44	.03	.09	16.00	48.00	.144
C_2	45-55"	1.23	.05	.15	8.20	24.60	.080
D	P. R.	.318	.005	.044	7.22	63.60	19.41

* Based on soil free of all combustible and volatile matter.

** These values were obtained by dividing the percent of each mineral by its molecular weight.

*** Bases include only Ca and K (Na determinations were not made).

Hagerstown Soil, being lower than that of any of the above horizons, indicates that there is either a loss of silica or an accumulation of alumina in the C horizon. The Clarksville profile showed the same trend as the Hagerstown profile but had a much higher sa ratio throughout.

The sf ratios showed the same trend as did the sa ratios. In the lower horizons of the Clarksville profile there appeared to be a considerable accumulation of iron oxide or a large loss of silica. On the other hand, this accumulation may be due to rock variation as brought out previously in this discussion.

The ba ratios were generally higher in the A or A_2 horizons than in the horizons beneath. In all cases these ratios brought out the fact that these soils have been thoroughly leached of their bases. This may be seen by comparing the ba ratio of the parent rock with that of the overlying horizons.

In order to show more clearly the chemical changes taking place in the development of these soils formed from the decomposition of limestone rocks, calculations of losses and gains of the constituents in each of the horizons were made. The calculations are shown in Table 4.

It was assumed in these calculations that no silica was lost during the formation of these soils, According to Merrill (14), who states that little or no silica is lost at decomposition of fresh carbonate rock, we are justified in making this assumption. The B_1, B_2 and C_2 horizons of Hagerstown silt loam showed an accumulation of alumina, but, as pointed out by Marbut (9), this so-called accumulation of alumina could also be a loss of silica. The C horizon of Pisgah silt loam and the B_1, C_1 and C_2 of Clarksville cherty silt loam showed an accumulation of iron oxide rather than aluminum oxide. In all cases the A or A_2 horizons had been leached to some extent of iron and aluminum oxides.

The loss of bases (Ca, Mg and K) during the soil forming processes is clearly brought out in Table 4. The calcium oxide was most thoroughly leached with a maximum loss of 99.99 percent. The magnesium oxide was also lost to a great extent ranging from approximately 98 percent in the Hagerstown profile to 99 plus percent in the Pisgah profile. Potassium was not lost as readily as the other bases, calcium and magnesium. In Hagerstown silt loam and Pisgah silt loam the amounts of potassium lost were much greater than that in Clarksville cherty silt loam. No explanation is offered for the relatively small amount of potassium lost during the formation of the Clarksville profile. The accumulation of P_2O_5 in the A_1 horizon of Clarksville was due to the high organic matter content of this horizon.

Table 4. The Percentage of Each Constituent Saved and Lost from Parent Rock of Hagerstown Silt Loam, Pisgah Silt Loam and Clarksville Cherty Silt Loam.

Horizon		SiO_2**		Fe_2O_3		Al_2O_3 and TiO_2		CaO		MgO		P_2O_5		K_2O		Loss on Ignition	
		Saved	Lost	Saved	Lost	Saved	Lost	Saved	Lost	Saved	Lost	Saved	Lost	Saved	Lost	Saved	Lost
HAGERSTOWN SILT LOAM																	
A_1	0-6"	100.0	0.0	59.54	40.56	74.64	25.36	.32	99.68	1.32	98.68	3.22	96.78	14.95	85.05	.60	99.40
A_2	6-10"	100.00	0.0	72.33	27.67	93.15	6.85	.38	99.62	2.05	97.95	2.99	97.01	13.86	86.14	.60	99.40
B_1	10-34"	100.0	0.0	81.54	18.46	102.17*	0.00	.34	99.66	1.86	98.14	3.13	96.87	16.04	83.96	.60	99.40
B_2	34-42"	100.0	0.0	86.60	13.40	119.46*	0.00	.34	99.66	2.03	97.97	3.92	96.08	16.44	83.56	.70	99.30
C	42-47"	100.0	0.0	97.09	2.91	141.57*	0.00	.37	99.63	2.42	97.58	4.79	95.21	17.57	82.43	.80	99.20
PISGAH SILT LOAM																	
A	0-8"	100.0	0.0	66.81	33.19	25.05	74.95	.02	99.98	.85	99.15	6.55	93.45	11.39	88.61	.60	99.40
B	8-38"	100.0	0.0	94.17	5.83	38.14	61.86	.01	99.99	.81	99.19	6.26	93.72	11.05	88.95	.32	99.68
C	38-45"	100.0	0.0	101.56*	0.00	35.71	64.29	.01	99.99	.82	99.18	5.80	94.20	10.47	89.53	.31	99.69
CLARKSVILLE CHERTY SILT LOAM																	
A_1	0-2"	100.0	0.0	85.89	14.11	35.03	64.97	.85	99.15	.62	99.38	318.83*	0.00	64.02	35.98	10.47	89.53
A_2	2-10"	100.0	0.0	64.75	35.25	22.80	77.20	.01	99.99	.25	99.75	57.54	42.46	59.76	40.24	.84	99.16
B	10-37"	100.0	0.0	100.26*	0.00	31.20	68.80	.01	99.99	.37	99.63	32.59	67.41	58.54	41.46	.62	99.38
C_1	37-45"	100.0	0.0	109.44*	0.00	45.75	54.25	.01	99.99	.59	99.41	97.55	2.45	54.88	45.12	.77	99.23
C_2	45-55"	100.0	0.0	213.57*	0.00	90.59	9.41	.01	99.99	1.30	98.70	112.72*	0.00	53.05	46.95	1.57	98.43

* Gain

** SiO_2 used as a constant factor.

Formula Used: $\frac{A}{B \times C} = X$

A = Percent of constituent in soil.

B = Percent of constituent in Parent Rock

C = $\frac{\text{Percent Silica in Soil.}}{\text{Percent Silica in Parent Rock.}}$

X x 100 = Percent saved

SUMMARY

The genetical and morphological characteristics of Hagerstown silt loam, Pisgah silt loam and Clarksville cherty silt loam, three southwest Virginia soils which were formed from material weathered from limestone, were studied by means of mechanical and chemical analyses, and field studies of the soil profiles.

The soils used in this investigation are all related in a general way, that is, they all occur within the Gray-Brown Podzolic region and arel all derivatives of relatively highly carbonated rocks.

Samples of all three soils were taken in Russell County, Virginia within the same vicinity. Therefore, the variations in the physical and chemical composition are due to variations in parent rock and relief and not to variations in climate.

Chemical analyses of the parent rock showed that the Hagerstown silt loam and Clarksville cherty silt loam were formed from material weathered from a dolomitic limestone, and that the Pisgah silt loam was formed from material weathered from a high grade limestone.

Total chemical analyses of the various horizons of the soil profiles showed that the soil forming processes of the three soils studied were podzolic in nature.

The parent materials or C horizons of all the soil profiles studied were clays. Hagerstown, which contained approximately 38 percent clay in the A_1 horizon and 75 percent clay in the C horizon, was the heaviest of the three soils studied.

Laboratory and field classifications of soil class conflicted in the case of the Hagerstown profile.

The ratios of silica to alumina, and silica to iron showed clearly the accumulation of alumina or iron in the lower horizons. The base to alumina ratio showed the thoroughness of the weathering of the three soil profiles.

Calculations of the percentages of bases lost during the soil forming processes showed that calcium was lost from the soil to a greater extent than the magnesium.

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