

A Survey of the Mineralogy of Indiana Soils^{1, 2}

J. L. WHITE, G. TALVENHEIMO,³ M. G. KLAGES⁴ and M. M. PHILLIPPE,⁵
Purdue University

Introduction

Twelve soil types which represent 33 percent of the total cultivated area of the State of Indiana were selected for mineralogical studies in connection with the development of quantitative x-ray diffraction procedures for the estimation of soil minerals (5, 7). These soil types were selected in order that the maximum variations of parent material, physiography, drainage phase and age group were represented. The salient features of the soil types investigated are presented in Table I.

TABLE I

General Description of Soils Used in This Study					
No.	Soil Type	Parent Material	Physiography	Major Profile	Age Group
1	Miami sil	Till-mixed	Upland	IV	2
2	Nappanee sil	Till-shale	Upland	II	2
3	Newton lfs	Outwash	Terrace	VIII	2
4	Fincastle sil	Till-mixed	Upland	II	3
5a	Crosby sil	Till-mixed	Upland	II	2
6	Cincinnati sil	Till-mixed	Upland	IV	4
7	Chalmers cl	Till-mixed	Upland	VIII	2
8	Clermont sil	Till-limy-shale	Upland	I	4
9	Frederick sil	Residual-cherty-limestone	Upland	IV	4
10	Zanesville sil	Residual-siltstone	Upland	IV	4
11	Fairmount sicl	Residual-shale-limestone	Upland	VI	4
12	Genesee sil	Alluvium	Bottom land	IV	1

Further information concerning the samples has been given by Breland (1).

Experimental

The surface horizons (A_p) of the twelve soils were separated into silt ($20-2\mu$) and coarse clay ($2-0.2\mu$) and fine clay ($<0.2\mu$) fractions.

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³ Present address: Houdry Process Corporation, Marcus Hook, Pennsylvania.

⁴ Present address: Department of Agronomy and Soils, Montana State College, Bozeman, Montana.

⁵ Present address: Agronomy Department, Clemson Agricultural College, Clemson, South Carolina.

The quartz and feldspar contents of the silt fractions were estimated by the x-ray diffraction procedure of Phillippe and White (5) and are shown in Table II. The mineralogical composition of the coarse clay fractions (Table III) was estimated by a combination of the x-ray

TABLE II

Mineralogical Composition of the Silt Fractions (20-2 μ) of the A _p Horizons of Twelve Indiana Soils				
No.	Soil Type	Mineralogical Composition, per cent		
		Quartz	Albite	Microlite
1	Miami sil	66	9	14
2	Nappanee sil	63	9	15
3	Newton lfs	47	10	13
4	Fincastle sil	65	9	14
5a	Crosby sil	67	9	14
6	Cincinnati sil	67	8	16
7	Chalmers cl	61	11	14
8	Clermont sil	81	7	9
9	Frederick sil	64	11	13
10	Zanesville sil	74	9	12
11	Fairmount sicl	73	8	14
12	Genesee sil	56	10	14

TABLE III

Mineralogical Composition of the Coarse Clay (2-0.2 μ) Fractions of the A _p Horizons of Twelve Indiana Soils						
No.	Soil Type	Quartz, per cent	Clay Mineral Composition Parts in ten of each constituent allowing ten per cent for material not registering			
			Montmoril- lonite	Illite	Vermiculite/ Chlorite	Kaolinite
1	Miami sil	14	0.8	3.1	3.5 (V/C)	1.6
2	Nappanee sil	14	0.6	4.9	2.3 (V)	1.2
3	Newton lfs	8	...	1.7	6.0 (C)	1.3
4	Fincastle sil	12	0.9	4.1	3.0 (V/C)	1.0
5a	Crosby sil	19	0.6	4.3	2.4 (V)	1.6
6	Cincinnati sil	13	0.9	4.4	1.9 (V)	1.8
7	Chalmers cl	10	1.0	4.9	1.6 (V)	1.4
8	Clermont sil	12	0.6	4.4	2.0 (V)	1.9
9	Frederick sil	10	0.8	3.6	3.3 (C)	1.3
10	Zanesville sil	12	...	4.3	3.8 (V/C)	0.9
11	Fairmount sicl	10	0.8	5.0	2.3 (V)	0.8
12	Genesee sil	7	1.5	4.7	2.2 (V)	0.6

diffraction procedures of Talvenheimo and White (7) and Johns, Grim, and Bradley (3).

The height of a particular diffraction peak above the background line (for example, BL in Fig. 1) was considered to be proportional to the amount of mineral present.

Results and Discussion

Mineralogical Composition. It is recognized that caution must be exercised in drawing conclusions on the basis of data from surface samples alone. The probable influence of loess on surface horizons in both the glaciated and unglaciated areas of the state and uncertainty of soil-parent material relationship seriously limit attempts to correlate mineralogical composition and the factors of soil formation presumed to be operative.

Some general trends are indicated in the data for the silt fractions. The older soils (Age Groups 3 and 4, Table I) tend to have a higher quartz content and a lower albite content. The relatively high content of sodium feldspar (albite) in the Frederick soil, presumed to be a very old residual soil, would indicate loess influence.

The data for the coarse clay fraction indicate that the residual soils, Nos. 9, 10, and 11, tend to be low in kaolinite. The montmorillonite content is highest in the Genesee and Chalmers soils. The 10 A. mica component in the clay fractions will be designated as "illite" even though the mica may be more closely related to muscovite. Grouped by illite (mica) content the soils rank as follows: high illite—Fairmount, Nappanee, Chalmers, and Genesee; intermediate illite—Fincastle, Crosby, Cincinnati, Clermont, and Zanesville; low illite—Miami, Newton, and Frederick. This grouping is in good agreement with the potassium-supplying power of these clays as given by Rouse and Bertramson (6). A mineral with an 001 reflection at 14 A. appears to be the second most abundant constituent in the coarse clays. It was surmised that the 14 A. mineral was a weathering product of illite.

The fine clay fractions ($<0.2\mu$) contain larger amounts of montmorillonite and illite than the coarse fractions. Kaolinite and quartz are present in small amounts, if at all.

Mica Weathering Sequence. Since the two most abundant constituents of the coarse clays are illite and a 14 A. mineral presumed to result from the weathering of the illite, it was considered worthwhile to examine the mica weathering sequence in more detail. Detailed examinations were made of soil profiles developed on Wisconsin glacial material (4). These soils included a Crosby silt loam [5b], a Miami silt loam, and a Chalmers silty clay loam. The findings for these soils were quite similar; the results for the Crosby [5b] will serve to illustrate principles involved in the weathering of mica in these and similar soils. The location of the Crosby [5b] profile was: Hancock County, NW $\frac{1}{4}$ of NE $\frac{1}{4}$ of Section 20, Township 16 N, Range 7 E. The horizons sampled, depth of sampling and pH were as follows: A₂ 4-11" (pH 5.4), B₂ 16-24" (pH 5.6), C 28" (pH 8.3).

Portions of the x-ray diffractometer tracings of the silt fractions are shown in Figure 1. Considerable amounts of dolomite and calcite

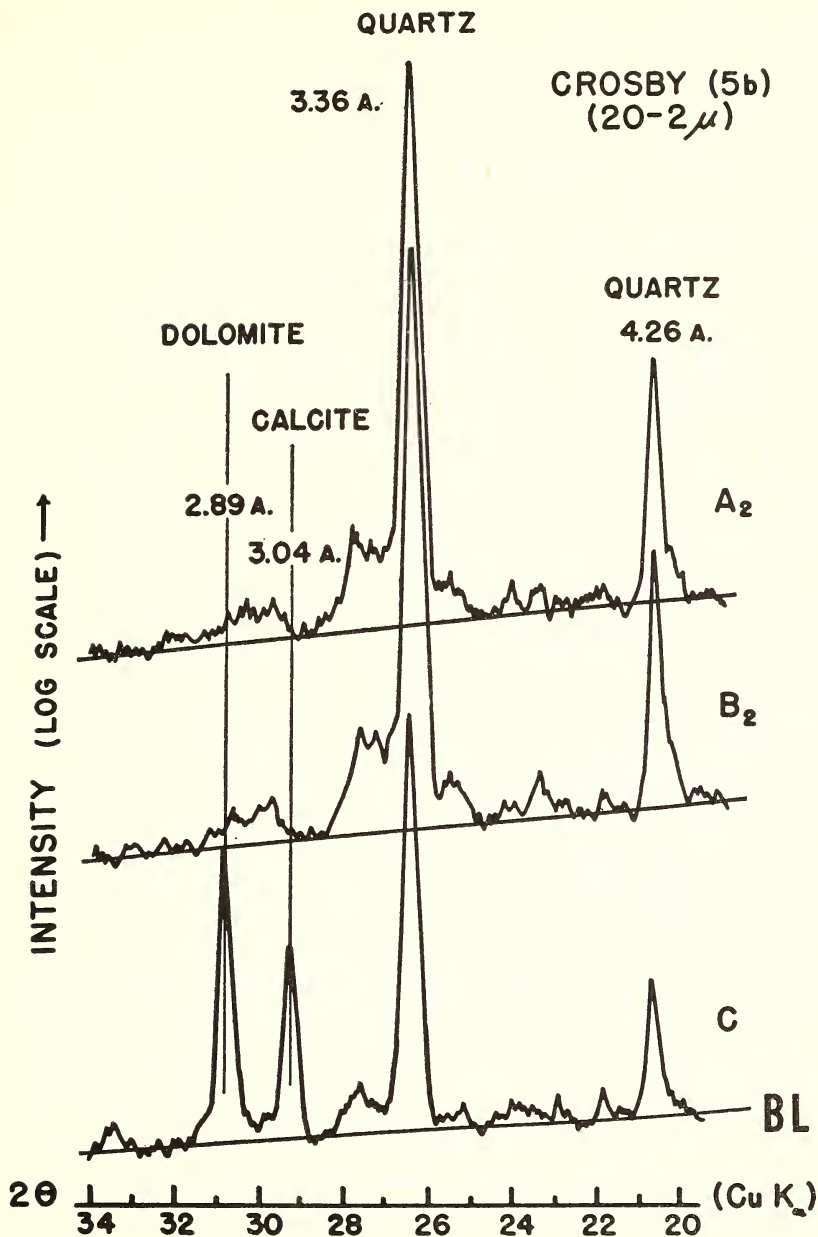


Fig. 1. X-ray diffractometer tracings of the silt fractions ($20-2\mu$) of the A₂, B₂, and C horizons of the Crosby [5b] soil. The background line is indicated by BL.

are present in the C horizon, but no detectable amounts in either the A₂ or B₂ horizon. The quartz content is about the same in the A₂ and B₂ but somewhat less in the C. Enrichment of quartz in the upper horizons has probably resulted from the weathering of the dolomite and calcite originally present.

Electron micrographs of the 2-1 μ fractions of the A₂, B₂, and C fractions revealed the morphological characteristics of the clay particles in all fractions to be similar. X-ray diffractometer tracings (Fig. 2) of coarse clay (2-0.5 μ) from the A₂ and C horizons show that the

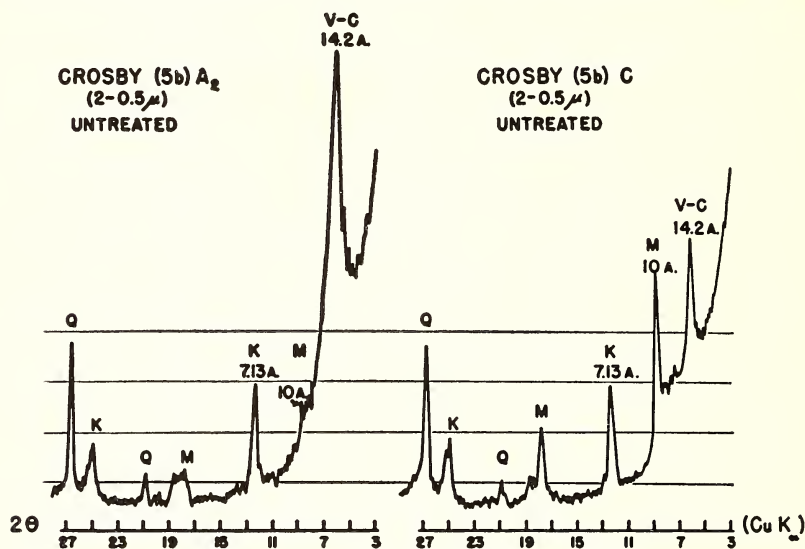


Fig. 2. X-ray diffractometer tracings of the coarse clay fractions (2-0.5 μ) of the A₂ and C horizons of the Crosby [5b] soil. The legend for the identification of the diffraction peaks is as follows: Q—quartz; K—kaolinite; M—mica (illite); V-C—vermiculite and/or chlorite.

quartz and kaolinite content of the two horizons are practically the same. The only apparent difference in the patterns is the decrease in the 10 Å. mica (illite) peak in the A₂ horizon with a consequent increase in the amount of 14 Å. mineral. It is concluded that the A₂ and B₂ horizons are genetically related to the C horizon in this Crosby soil and that weathering conditions have been relatively mild.

Since the illite in the fresh Wisconsin glacial till is a dioctahedral mica (4), the material which expands to 14 Å. is equivalent to the dioctahedral analogue of vermiculite described by Brown (2). Vermiculite should collapse from 14 Å. to 10 Å. on heating to 300° C. Heating tests (Fig. 3a, b, c) on the 2-0.5 μ fraction of the Crosby [5b] horizons showed that the 14 Å. mineral collapsed rather completely to 10 Å. in the B₂ and C horizons, but there was little increase in the intensity of the 10 Å. spacing in the A₂ horizon on heating. This indicates the

Figure 3a

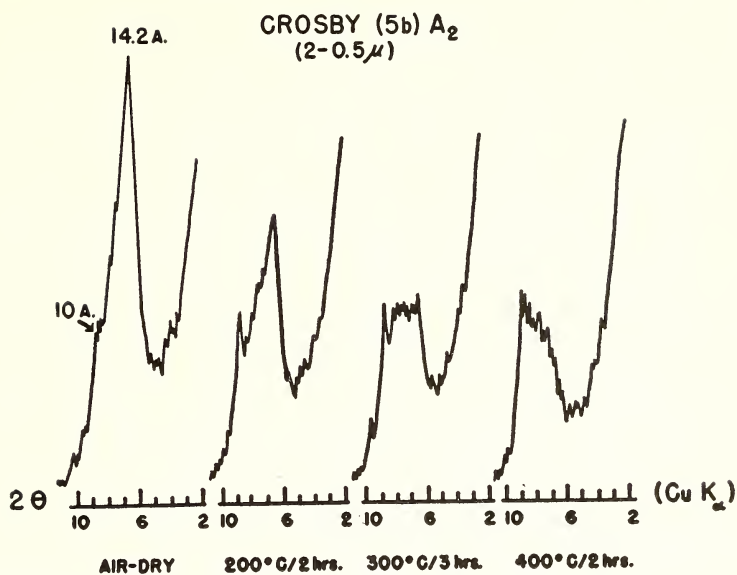


Figure 3b

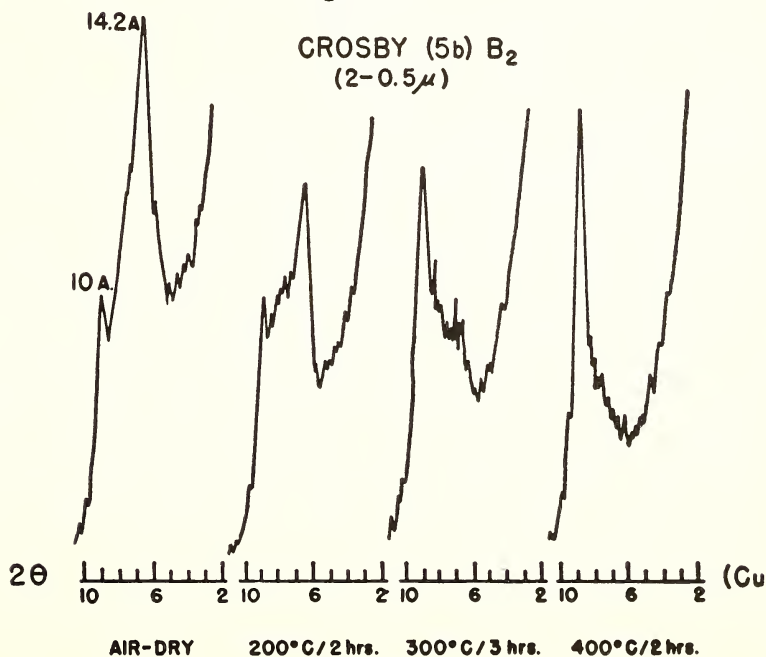


Figure 3c

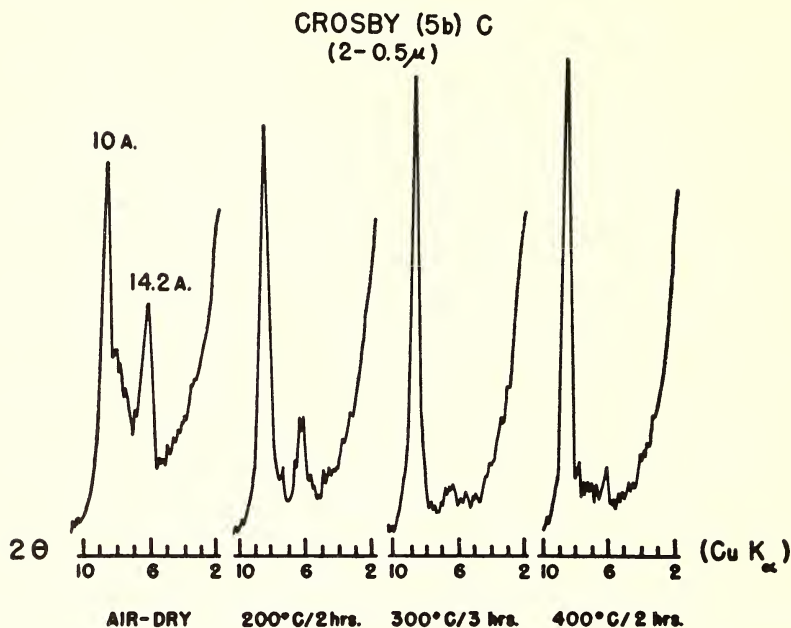


Fig. 3a, b, c. The effect of heat treatment on the collapse of the 14 A. mineral in the Crosby [5b] coarse clay fractions.

presence in the A₂ horizon of inter-layer material which prevents complete collapse of the plates. Klages (4) postulated the presence of positively-charged partially-hydrated aluminum hydroxide between the weathered mica layers in this material. As the amount of the complex aluminum cation increases the properties of the mineral would shift from that of a vermiculite toward a chlorite. Acid weathering conditions would give rise to such complex aluminum cations, and with increasing soil acidity there should be an increase in the amount of the complex aluminum cation occupying exchange positions in the weathered mica. This would result in an increase in the resistance of the 14 A. mineral to collapse on heating. The coarse clay fractions of three soils derived from Wisconsin till, and having pH values from 8.3 to 5.0 were chosen to indicate the effect of soil pH on the thermal stability of the 14 A. mineral. The soils and pH values are as follows: Crosby [5b] C pH 8.3; Miami [1] A_p pH 6.2; Newton [3] A_p pH 5.0. From Figure 4 it is evident that with increasing acidity there is a decrease in the proportion of the 14 A. mineral which can be made to collapse completely to 10 A.

Soils micas which behave similar to the Crosby [5b] C have been designated in Table 3 as vermiculite (V); those behaving similar to

Miami [1] A_p have been designated as intermediate between vermiculite and chlorite (V/C); those reacting in a manner like the Newton [3] A_p have arbitrarily been called chlorite (C). It is recognized that the Newton clay is not a true chlorite, but its thermal stability indicates it is an intergrade between vermiculite and chlorite and it is here considered as being more closely related to chlorite.

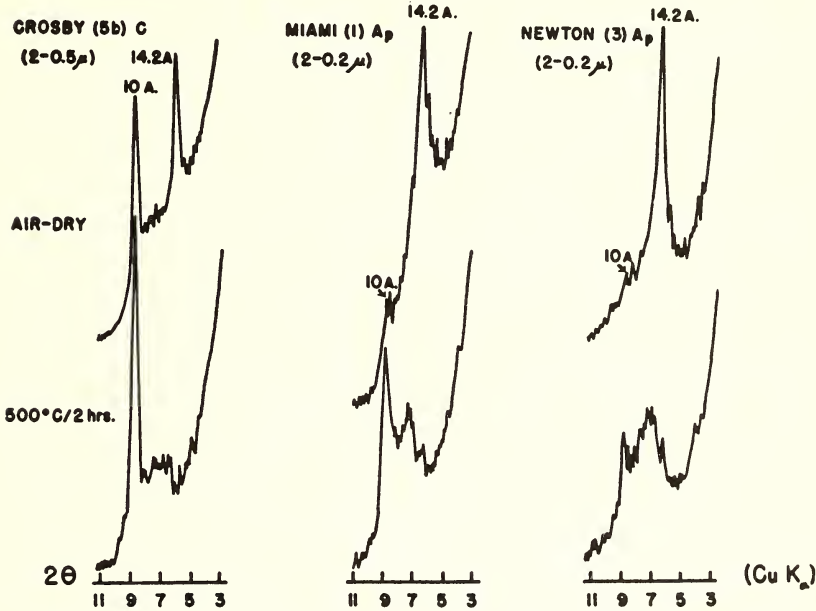


Fig. 4. The effect of soil pH on the thermal stability of the 14 Å mineral in the coarse clay fractions of the Crosby [5b] C (pH 8.3), Miami [1] A_p (pH 6.2), and the Newton [3] A_p (pH 5.0) horizons.

Some of the properties of weathered micas are of considerable agronomic significance. For example, a high layer charge on the clay may result in potassium entrapment or "fixation." This is illustrated for the Fairmount clay in Figure 5 by the effect of potassium-saturation and air drying in collapsing a considerable proportion of the 14 Å mineral to 10 Å. The availability of potassium to plants is reduced by such a reaction. Under acid weathering conditions the aluminum hydroxide cation complexes may occupy exchange positions and reduce the tendency for potassium fixation to occur. The presence of aluminum hydroxide cation complexes in weathered micas may also be an important factor in controlling the activity of aluminum ions in the soil solution. This becomes significant in its effect upon the phosphate equilibrium in the soil.

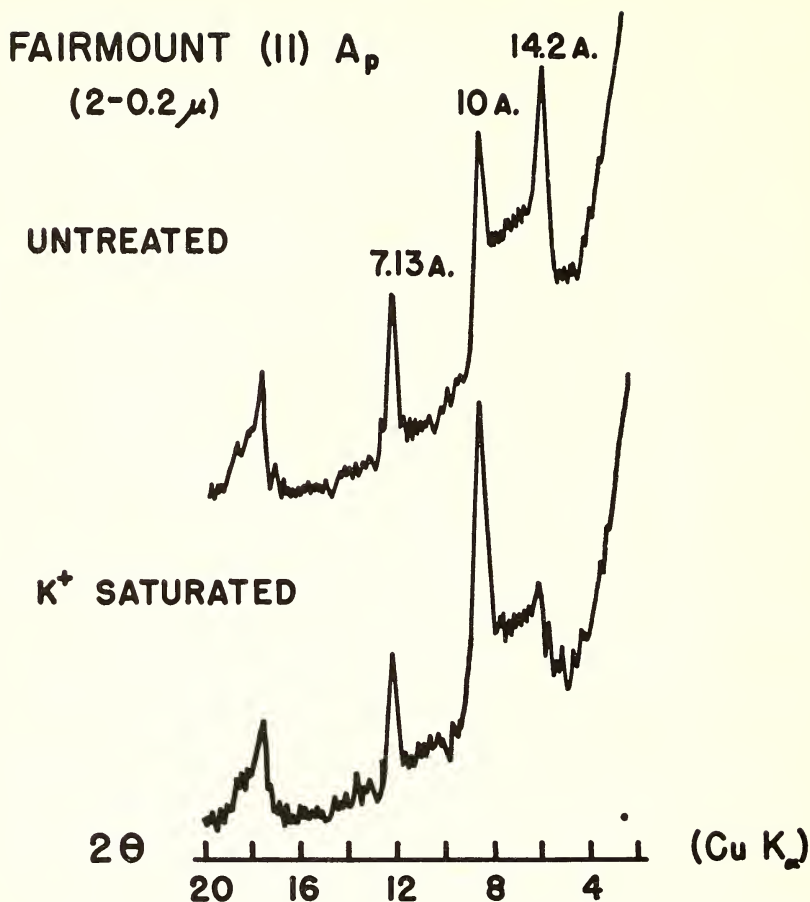


Fig. 5. The effect of potassium-saturation on the collapse of the 14 A. mineral in the Fairmount [11] A_p coarse clay fraction.

Summary

Mineralogical studies of twelve soil types which represent 33 percent of the total cultivated area of the State of Indiana indicate that the predominant constituents of the clay fractions of these soils are quartz, kaolinite, mica and vermiculite-chlorite assemblages.

Detailed mineralogical studies of the Crosby, Miami, and Chalmers soils reveal that the most prominent weathering trend in the clay fractions of soils derived from glacial till is the mica-vermiculite-chlorite sequent.

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