MINERALOGIC TRENDS INDUCED BY DEEP RESIDUAL WEATHERING

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Abstract

X-ray diffraction data obtained from samples from seven vertical profiles in the thick residual mantle of the North Carolina piedmont reveal significant mineralogic changes which are related to the character of the parent rock material and to the degree and conditions of weathering.

In the soils derived from granitic and gneissic rocks the reduction of particle size of mica as weathering progresses facilitates its conversion to intergradational vermiculite-chlorite. The relative amount of kaolinite decreases as the content of other secondary components of the soil increases, but this does not necessarily indicate a decrease in the absolute abundance of kaolinite.

Saprolite on a serpentinite body contains abundant chlorite and talc. Feldspar and kaolinite are important constituents of the lower part of the C horizon, and become progressively less important upward into the A horizon.

Introduction

In the Piedmont area of the southeastern United States, between the Blue Ridge on the west and the Coastal Plain on the east, deep residual soils have formed over a variety of rock types. This situation provides an excellent opportunity to examine mineralogic trends that have developed as a result of residual weathering.

In Wake County, North Carolina, several localities have been sampled and the mineralogy of the samples determined by x-ray diffraction analysis. The samples were prepared according to the procedure described by Jackson (1956) and by Jackson and Milford (1962) with some slight modifications. The material was fractionated into clay size (less than two microns), fine silt size (two to twenty microns), and coarse silt size (twenty to fifty microns) fractions. The clay and fine silt size fractions were magnesium-saturated and were mounted and dried on glass slides to obtain parallel orientation of the particles. The coarse silt fraction was taped to a glass slide. All of the samples were irradiated by an x-ray beam from a General Electric XRD-5 spectrometer, using Cu Kα radiation. The percentages of each constituent in the samples were computed by measuring peak heights of first order x-ray reflections above background on a pattern for a given sample. The percentages were normalized to obtain the relative amounts of each constituent in each sample.[2]

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[2] Based on method proposed by Dr. Leon Johnson, Pennsylvania State University, University Park, Pa. Personal communication.

TABLE 1. DIFFRACTION SPACINGS USED FOR MINERAL IDENTIFICATION.
SAMPLES Mg-SATURATED, IRRADIATED AT ROOM TEMPERATURE.

d/n spacing, Å	Mineral
14.2–14.5	Montmorillonite,[1] intergradational vermiculite-chlorite, vermiculite[2]
11.8–12.4	Random mixture of illite-vermiculite
9.6–10.0	Clay mica or illite
9.4	Talc
8.35–8.40 (3.18)	Amphiboles
7.19	Kaolinite
4.27	Quartz
4.15–4.19	Goethite
3.17–3.21	Feldspar

[1] Montmorillonite identified by 17.6 Å spacing following treatment with glycerol, and by subsequent 14.2 Å spacing after heating to 350° C. for 30 minutes.

[2] Vermiculite, chlorite and intergradational vermiculite-chlorite identified by structural responses to heating to 350° C. Vermiculite collapses to 10 Å, chlorite remains at 14 Å, and intergradational vermiculite-chlorite shifts between 10 and 13.9 Å.

Percentages determined in this manner are semiquantitative and relative, with an accuracy range of about 10%. Additional treatment was required to distinguish between montmorillonite, intergradational vermiculite-chlorite, vermiculite, and chlorite. The basis for identification of the mineral constituents is shown in Table 1.

DESCRIPTION AND MINERALOGY OF SAMPLES

In the samples analyzed, the minerals which occur most frequently are kaolinite (including halloysite), intergradational vermiculite-chlorite, a random mixture of illite and vermiculite, clay mica or illite, and remnant quartz, mica, feldspar and amphibole. Montmorillonite is present in one sample; talc and chlorite occur in the weathering products derived from serpentinite.

Figure 1 is a composite bar graph showing the percentages of the various constituents found in the weathering products produced from biotite granite. The parent rock is fine-to-medium-grained, and is composed of about 35% quartz, 60% feldspar and 5% mica. The feldspar is predominantly microcline, although some plagioclase is present. The mica is biotite, pleochroic from light gray-green to opaque. The biotite granite saprolite is variegated in color, with light gray, brownish, and reddish yellow streaks. The surface soil is Cecil loamy fine sand.

In the saprolite, as represented by the lower three samples included in Fig. 1, the kaolinite content decreases upward, especially in the silt size fractions. In the clay size fraction the upward decrease in kaolinite is not
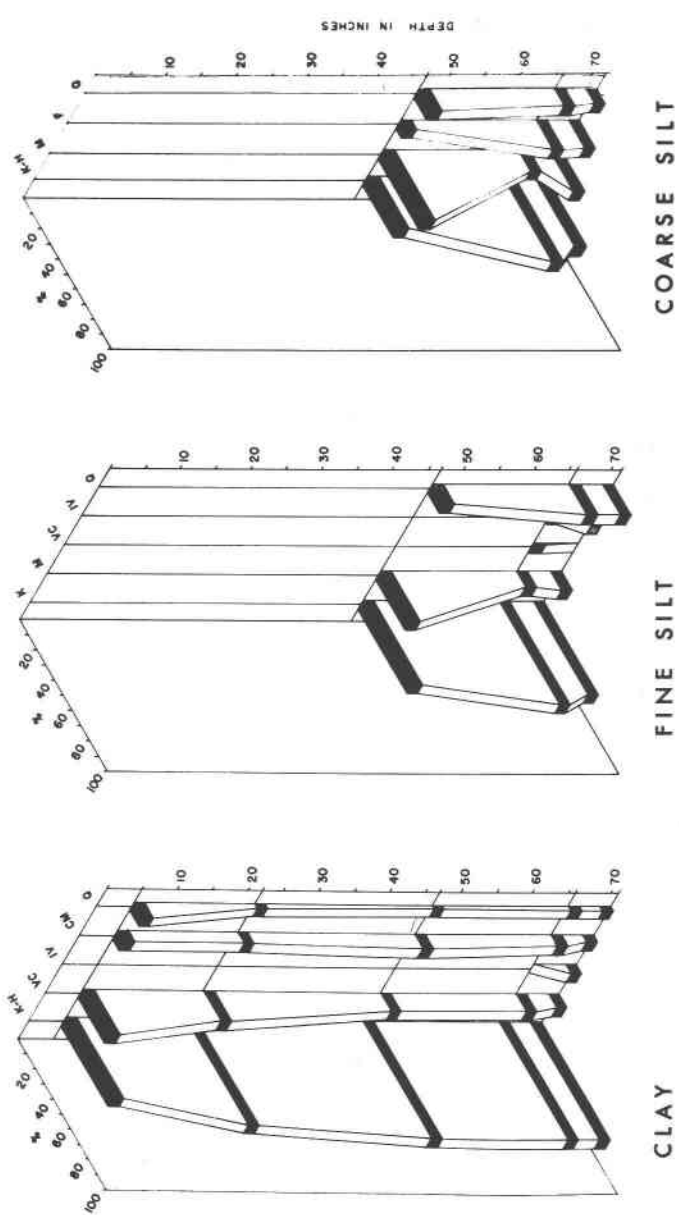
FIG. 1. Mineralogy of clay, fine silt, and coarse silt size fractions of soils derived from biotite granite. Explanation of symbols: A = amphibole, Cl = chlorite, CM = clay mica or illite, F = feldspar, IV = random mixture of illite-vermiculite, K = kaolinite, K-H = kaolinite and halloysite, M = mica, Mo = montmorillonite, Q = quartz, T = talc, VC = intergradational vermiculite-chlorite.

apparent in the saprolite, but is pronounced in the B (22-inch depth) soil horizon, and becomes very significant in the A (5-inch depth) soil horizon. Mica is present in the coarse and fine silt sizes, and its percentage increases in the saprolite. This upward increase may be caused by the diminution of particle size as weathering increases, producing a relative increase in mica content in these fine particle size fractions as weathering progresses. Vermiculite-chlorite, an important constituent only in the clay size fraction, increases upward, especially in the A horizon. Illite-vermiculite is a very minor constituent in these samples, and clay mica is present only in the clay size fraction. Feldspar occurs in the coarse silt size fraction, decreasing upward toward the top of the saprolite.

The parent material of the sample illustrated in Figure 2 is biotite gneiss, composed of 40 to 60% quartz, 15 to 25% plagioclase (dominantly andesine, but with some oligoclase), 1 to 5% potassium feldspar, (dominantly orthoclase), 10 to 20% biotite, 5 to 15% muscovite, and minor accessory minerals. The saprolite developed from this rock is dark reddish brown in color, and the surface soil is Cecil fine sandy loam in which the B horizon is a red clay containing quartz and weathered mica.

Kaolinite is the dominant constituent in the saprolite, as indicated by the lower three samples included in Fig. 2. In passing upward from saprolite into B horizon (16-inch depth), and particularly from B to A horizon (4-inch depth), the kaolinite percentage decreases significantly. Illite-vermiculite is important only in the saprolite, in the fine silt fraction.

Vermiculite-chlorite is a major constituent in all size fractions, and is the dominant clay mineral in the A horizon; clay mica is present in minor amounts. Relict mica is abundant in the silt fractions, decreasing upward in the coarse silt, but increasing upward in the fine silt, probably as a result of the breakup of mica particles as weathering progresses. Feldspar is present in the coarse silt size only, and disappears completely within the deeper horizons.

The composition of the weathering products developed from muscovite gneiss is shown in Fig. 3. The parent gneiss is light gray in color, with a distinct salt and pepper effect. It is coarse-to-fine-grained, with average grain size between 1 mm and 5 mm. Mica-rich bands alternate with quartzo-feldspathic bands, and the bulk mineralogy includes 40 to 60% quartz, 20 to 40% feldspar, 5 to 20% muscovite, 5 to 15% biotite, and minor accessory minerals. The quartz grains are strained and many are fractured. The dominant feldspar is plagioclase, oligoclase to andesine in composition. The saprolite from this rock is micaceous, reddish gray in color, and contains well preserved relict gneissic structure. The soil at the surface is moderately eroded Appling fine sandy loam, with a strong brown clay B Horizon.
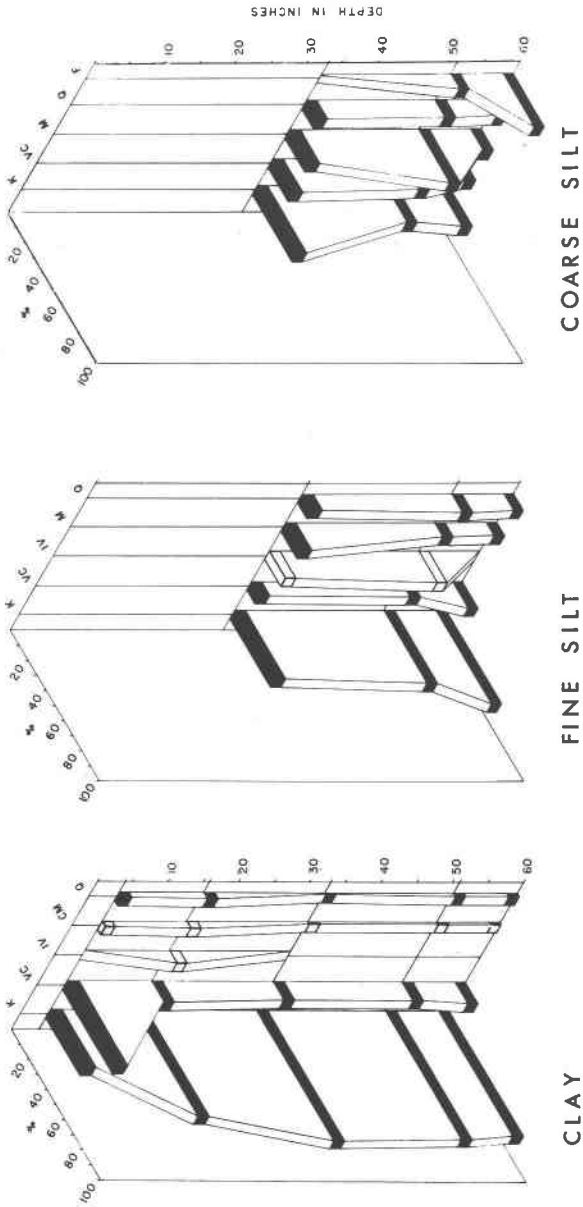
FIG. 2. Mineralogy of clay, fine silt, and coarse silt size fractions of soils derived from biotite gneiss. For explanation of symbols, see Fig. 1.
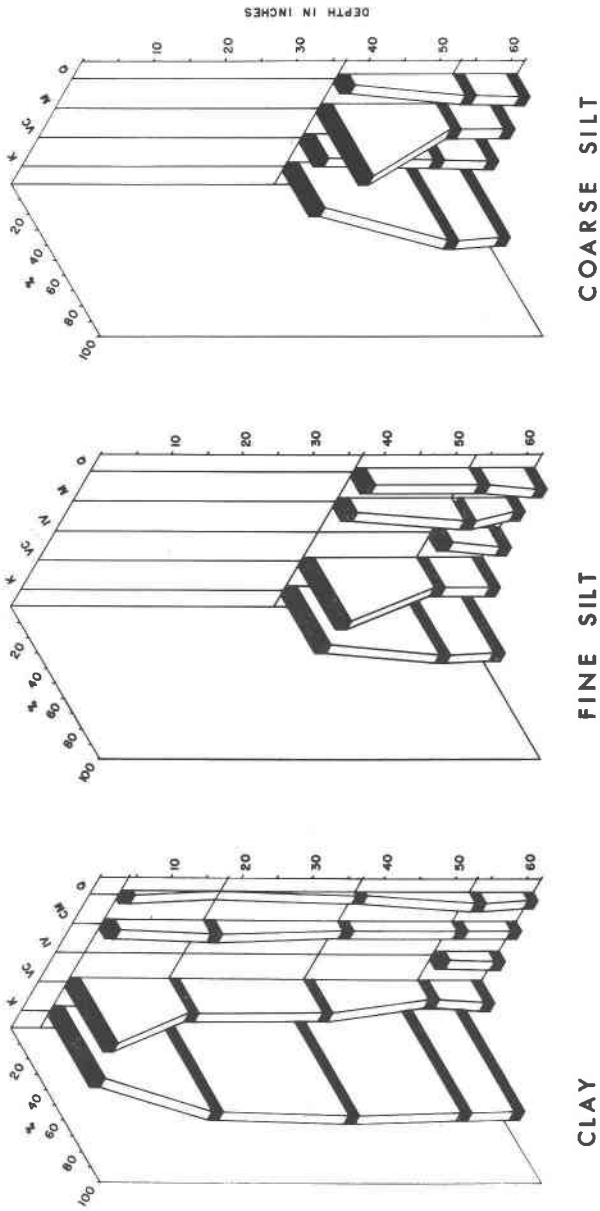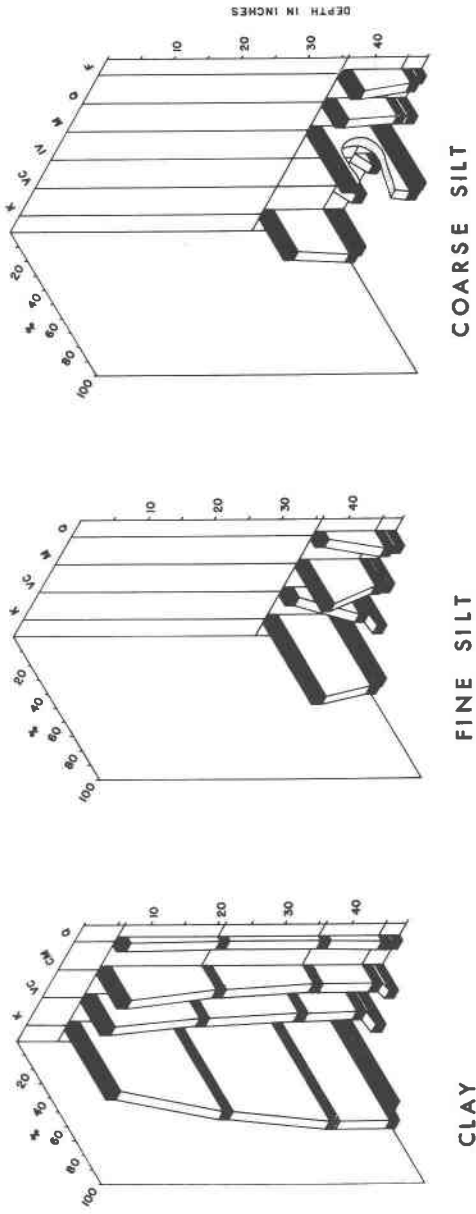
M U S C O V I T E   G N E I S S

FIG. 3. Mineralogy of clay, fine silt, and coarse silt size fractions of soils derived from muscovite gneiss. For explanation of symbols, see Fig. 1.

Kaolinite is the dominant constituent of the weathering products of the muscovite gneiss. Its relative abundance tends to decrease upward, especially in the A horizon (4-inch depth), and to a lesser extent in the saprolite (37-inch depth and below). The vermiculite-chlorite content increases upward as the kaolinite content decreases, especially in the A horizon. Finely divided illite-vermiculite is present in the fine silt and clay in the deeper part of the saprolite, and clay mica occurs in the clay size only. The total content of relict mica in the saprolite, considering the coarse and fine silt sizes together, increases upward.

The parent material of the samples illustrated in Fig. 4 is fine- to medium-grained mica-hornblende gneiss containing as much as 80% hornblende, with accessory chloritized biotite and muscovite. Oligoclase feldspar is a relatively minor constituent, and quartz, epidote and chlorite occur as minor accessory minerals. The saprolite developed from this rock is dark brownish red in color and retains the gneissic foliation and well defined joint system of the parent rock. The residual soil is Cecil fine sandy loam, in which the B horizon is red clay. Kaolinite is the predominant constituent in the weathered material, but its relative abundance decreases upward into the B horizon (21-inch depth), and even more so in the A horizon (6-inch depth). Similarly, vermiculite-chlorite decreases upward in the saprolite, but unlike kaolinite, shows a slight increase in the A horizon. Illite-vermiculite is present only in the coarse silt fraction, in the deep saprolite. Clay mica occurs in the clay size fraction, more abundantly in the A horizon than in the deeper samples. In the coarse silt fraction the mica content decreases upward in the profile, but this upward decrease is accompanied by a corresponding upward increase of mica in the fine silt fraction. Some feldspar is present in the coarse silt sample.

The quartzose gneiss (Fig. 5) is a fine-grained granoblastic to lepidoblastic rock containing small schistose mafic and graphitic lenses. White and pink bands of quartz and feldspar predominate, and are separated by foliated bands containing muscovite and biotite. The quartz content averages about 80% of the volume of the rock. The feldspar is predominantly orthoclase and/or microcline, with a minor amount of sodic plagioclase. Muscovite and biotite make up a small portion of the rock, with muscovite usually predominant. Foliation inherited from the parent rock is well preserved in the saprolite, and the surface soil is micaceous Cecil fine sandy loam.

The dominant mineral in the saprolite and soil derived from the quartzose gneiss is kaolinite, and its relative abundance increases upward in the profile from the lowest samples (76-inch depth) to the B horizon (23-inch depth), and then decreases in the A horizon (4-inch depth). Illite-vermic-

FIG. 4. Mineralogy of clay, fine silt, and coarse silt size fractions of soils derived from mica-hornblende gneiss. For explanation of symbols, see Fig. 1.
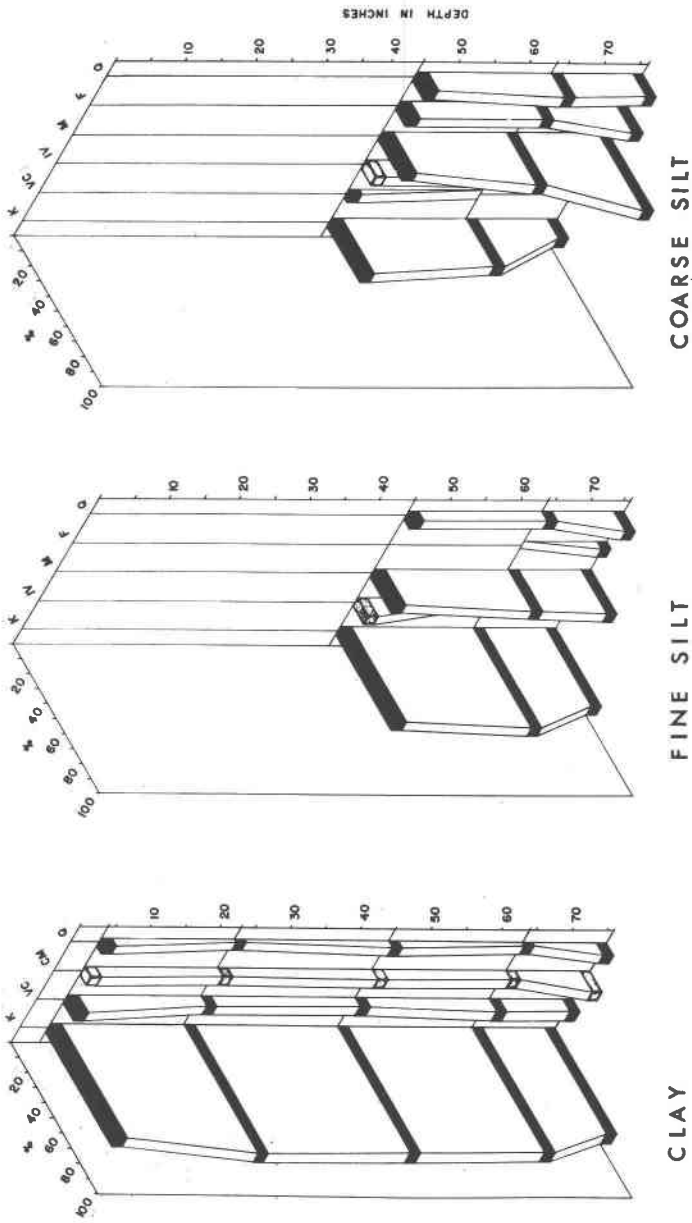
FIG. 5. Mineralogy of clay, fine silt, and coarse silt size fractions of soils derived from quartzose gneiss. For explanation of symbols, see Fig. 1.

ulite is present in the silt size fractions in the upper part of the C horizon, (45-inch depth), but does not occur in the clay size fraction. Vermiculite-chlorite and clay mica are minor constituents; mica and feldspar tend to disappear upward in the profile as the degree of weathering increases.

The medium- to coarse-grained granodiorite gneiss (Fig. 6) has weakly developed schistosity and is composed of 30 to 60% feldspar, 5 to 25% quartz, 10 to 25% biotite and 3 to 5% hornblende. The feldspar is dominantly andesine, but an appreciable quantity of orthoclase is present. The saprolite developed from this rock is micaceous, light gray to dark reddish in color. The surface soil is friable brown Enon fine sandy loam; on the upland surfaces, erosion has removed the A horizon.

Kaolinite and halloysite are significant constituents of the soil. These minerals increase in relative abundance upward in the profile through the saprolite, (30-inch and 21-inch depths), and then decrease in the B (10-inch depth) and A (4-inch depth) horizons. In contrast, the vermiculite-chlorite content decreases upward in the saprolite, and increases in the B and A horizons. Illite-vermiculite and clay mica are minor constituents. The relict mica content is negligible, but feldspar and a small quantity of amphibole are present in the saprolite. The clay size fraction of the saprolite contains an appreciable quantity of montmorillonite.

Serpentinite (Fig. 7) is found in several areas of the Piedmont. Its color is light to medium green, mottled, and it has coarse-to medium-granular texture. Mineralogically, the serpentinite is dominantly antigorite, with varying amounts of chlorite, talc and carbonate. Chromite and pyroxene are present as minor constituents. The saprolite developed from the serpentinite is dark reddish brown and has a granular texture. The surface soil is Wilkes fine sandy loam, dark grayish brown in color. The B horizon is not recognizable in the soil profile, so the samples collected represent only A horizon (5-inch depth) and saprolite (22-inch, 47-inch, and 60-inch depths).

The most abundant constituents in the serpentinite soil samples are chlorite and talc, the chlorite being dominant in the clay size fraction and the talc in the silt size fractions. Kaolinite (and halloysite) are major constituents of the deeper samples, and decrease in abundance upward in the soil profile. Vermiculite-chlorite is an important component in the coarse silt size fraction, but illite-vermiculite and relict mica occur only in the deepest samples. An appreciable quantity of feldspar and a small amount of quartz are present in the saprolite.
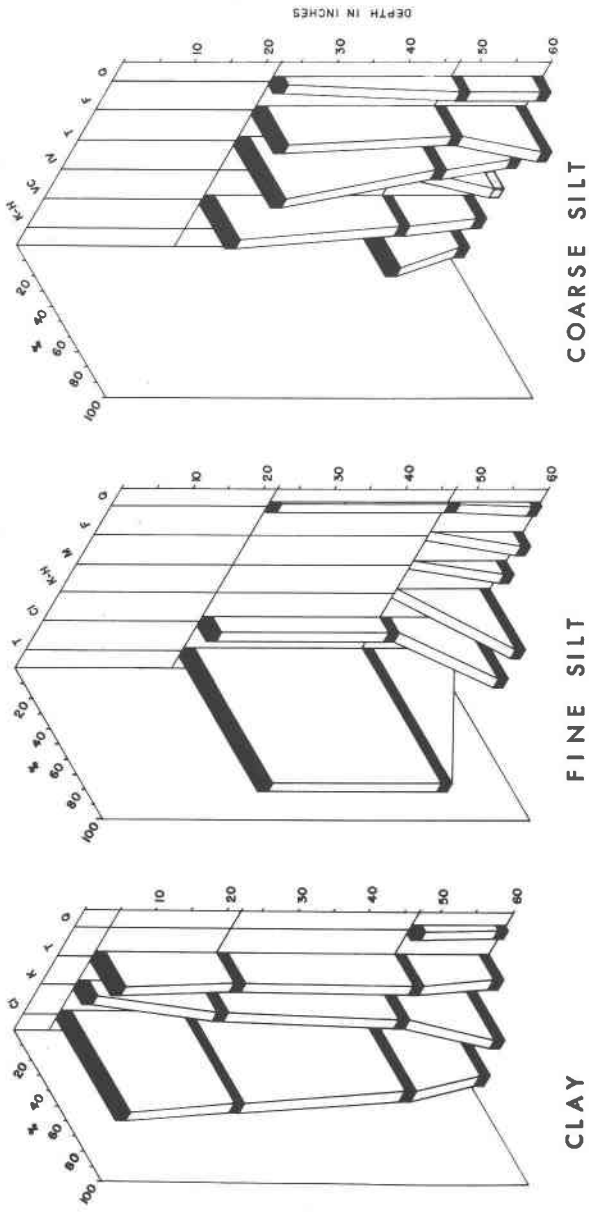
CONCLUSIONS

The data generally conform with the relative stability of coarse grained minerals as proposed by Goldich (1958), and with the weathering
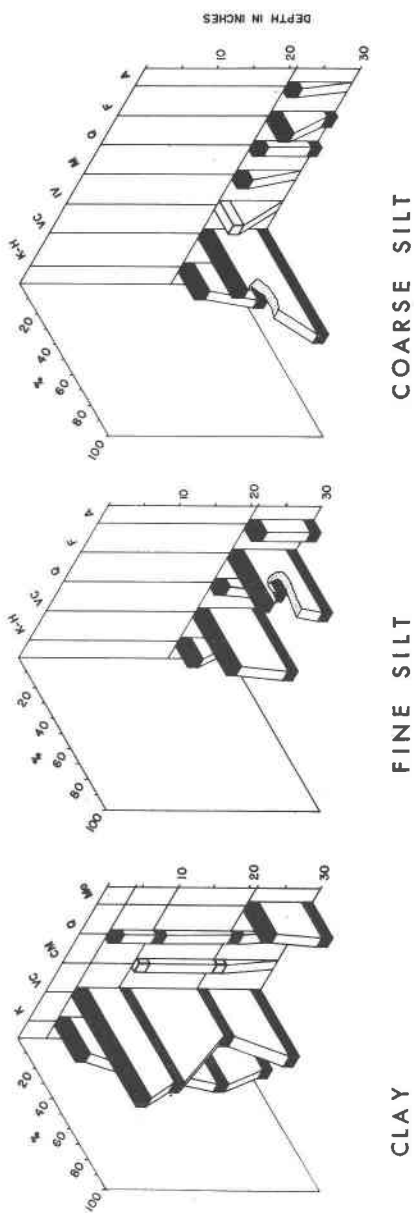
Fig. 6. Mineralogy of clay, fine silt, and coarse silt size fractions of soils derived from granodiorite gneiss. For explanation of symbols, see Fig. 1.

GRANODIORITE GNEISS

COARSE SILT

FINE SILT

CLAY

FIG. 7. Mineralogy of clay, fine silt, and coarse silt size fractions of soils derived from serpentinite. For explanation of symbols, see Fig. 1.

sequences of clay sized-minerals as discussed by Jackson and Sherman (1953). Progressive effects of weathering are especially apparent in the relationships shown by mica and vermiculite-chlorite. Because of the physical breakdown of larger mica flakes during the weathering process, the relative abundance of mica in the silt size fractions of most of the samples increases as the sample depth in the profile decreases. The rate of conversion of mica to vermiculite-chlorite apparently is accelerated as the particle size of the mica is reduced. The vermiculite-chlorite content of the A horizon samples is significantly greater than in samples from the deeper horizons.

In all of the profiles the relative abundance of kaolinite is less in the A and B horizons than in the saprolite. The method used to interpret the *x*-ray data does not provide measures of absolute abundance of the various constituents, so it is entirely possible that the decrease in relative abundance of kaolinite is caused by the increase in relative abundance of vermiculite-chlorite and, to a lesser extent, of the other components of the samples. The same may be said for the relative increase in talc in the silt size fractions in saprolite derived from serpentinite, and perhaps also for the increase in relative abundance of chlorite in the clay size fraction of the serpentinite soil.

Feldspar persists in the saprolite in several profiles, but disappears in the thoroughly weathered A horizon samples. A small amount of amphibole is present in the granodiorite gneiss saprolite, and montmorillonite occurs in the clay size fraction of this material. Neither of these constituents is found in the more thoroughly weathered A and B horizon samples.

It is hoped that the data obtained from this study, though semiquantitative, will lead to further investigations of weathering-induced mineralogic trends. These data should prove to be significant in ground water studies, as well as in geochemical interpretations of rock weathering and soil genesis.

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