

KAOLINITE STABILITY IN THE CENTRAL PIEDMONT OF GEORGIA

by

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ABSTRACT

A STUDY of weathered profiles from fresh rock to the surface in granitic rocks and biotite-plagioclase gneiss shows the following: 1. The particle size of the kaolin increases from not subject to estimate in fresh rock to a maximum of approximately 60μ in the vicinity of the contact between the B horizon and the saprolite, then it decreases to approximately 13μ in the A horizon. 2. Gibbsite occurs most abundantly when the abrasion pH of rock slurries is greater than 6 or less than 5.5. In outcrop, gibbsite is abundant in the upper soil horizons and in the partially weathered rock but is sparse in the intervening saprolite. 3. The total amount of kaolin increases steadily upward from zero in fresh rock to a maximum in the B horizon then declines sharply in the A horizon.

These data are interpreted to mean that kaolin forms, grows and is stable in saprock, saprolite and B horizon, but it is not stable in the upper B and A horizons or in the very basic environment of incipient weathering.

INTRODUCTION

THE OBJECT of this work was to compare the distribution of kaolin in the weathering environment holding climate, vegetation and topography nearly constant but varying the parent rock. Two rocks were used: the biotite-plagioclase gneiss and several different granitic rocks ranging from adamellite to granodiorite in composition. The biotite gneiss is composed of approximately 30 per cent biotite, 40 per cent oligoclase, 30 per cent quartz and minor amounts of epidote, pyrite, garnet and muscovite. The granitic rocks vary in the relative proportions of biotite and muscovite and in the proportion of oligoclase to microcline. The composition is approximately 60 per cent feldspar, 30 per cent quartz and 10 per cent mica.

The term *kaolin* is used to denote either halloysite, endellite or kaolinite, all of which may occur in the weathering profile.

All samples, as far as can be determined, represent residual material selected from excavations, borings or road cuts in wooded areas that have been out of cultivation for at least 15 yr. Present vegetation on sample sites consists mainly of pine and hardwood trees.

The climate is warm and moist with approximately 50 in. of rainfall, which is fairly evenly distributed throughout the year.

The topography is gently rolling with the local relief of the order of 100 ft. All samples were taken from hilltops or broad level areas.

In all, 169 samples were taken, 100 biotite gneiss and 69 granitic rock residua. The weathering profile was sampled to obtain, from the surface downward, the A, B, saprolite and saprock horizons. In most localities it was not possible to collect from all horizons at a given site.

In the biotite gneiss, these horizons are recognized as follows: The foliated gray saprock is friable with difficulty. It looks like fresh rock except that the feldspars are chalky. The grayish saprolite is more weathered than the saprock and so soft it easily crumbles in the hand. It retains the texture and general appearance of the fresh rock. The B horizon is a heavy, brick-red clay that shows neither structural nor mineralogic affinity with the underlying saprolite. It is clearly a zone of accumulation. The A horizon is usually brownish or grayish brown, contains some organic matter and tends to be much less clayey than the underlying B horizon. Overlying the A horizon is a layer, 1–2 in. thick, composed mainly of decomposing leaves, sticks, and other plant debris. This layer was avoided, since it contains little inorganic matter.

The weathering profiles of the granitic rocks are similar to those of the biotite gneiss. The saprolite and saprock are mechanically like the gneiss but differ in texture and are lighter colored, usually white or buff. B horizons are pale red or brownish when derived from biotite-poor rocks and brick red from biotite-rich rocks. A horizons are grayish white and contain obvious quartz sand. A layer of leaf mold overlies the A horizon.

PROCEDURES

Sampling was done by digging in roadcuts and excavations or by soil auger. Samples were placed in plastic bags. Samples of A horizon were collected so as to eliminate most organic material.

Laboratory study included the use of differential thermal analysis and of the petrographic microscope. Mechanical analyses were done on 45 samples using the hydrometer technique (Bouyoucos, 1928).

Determination of the percentage of kaolin in the samples is based on data obtained from prepared standards. The standards were prepared by removing the clay fraction from A- and B-horizon residuum, then adding back various known amounts of refined kaolinite and then running these on the DTA. The resulting curve was used to determine the percentage of kaolin in all samples of A- and B-horizon material. Saprolite and saprock were referred to curves prepared for this type of material. The difference between the two curves is very slight.

Gibbsite was not measured directly but by estimation relative to kaolin. This was done by adding the amplitude of kaolin's 600° endothermic peak to the amplitude of the 320° gibbsite endothermic peak, measured in millimeters, and taking the percentage of gibbsite peak as a proportion. These estimates are utilized in Figs. 5, 6, 7 and 8.

TABLE 1.—MAXIMUM PARTICLE SIZE OF KAOLIN

	Equivalent spherical diameter, microns			Number of samples
	A Horizon	B Horizon	Saprolite	
Granitic Rocks	12	35	42	15
Biotite Gneiss	13	61	60	30

Determination of the maximum kaolin particle size, as shown in Table 1, was made by using the mechanical analysis curve, as obtained by the hydrometer technique, and the DTA-determined percentage of kaolin in the sample. The percentage of kaolin is laid off on the mechanical analysis curve, from the clay-size end. The maximum equivalent spherical diameter of kaolin in microns is read from the curve. Microscopic measurements made in thin sections of weathered material tend to support these data. In saprolites, the value of this technique declines because of occlusion of clay particles within partially decomposed but large feldspar and mica grains. In saprock, the technique is worthless.

The pH determinations are by the abrasion technique. This involves grinding a sample in distilled water in an agate mortar for $2\frac{1}{2}$ min.

Gibbsite is identified by its 320°C endothermic peak and is differentiated from goethite by its solubility in hot 5 per cent NaOH solution (Carroll and Jones, 1947, p. 4). The red coloration particularly notable in the B horizon is removable by acids and is probably goethite.

In the differential thermal analysis of all samples, the temperature of the major endothermic peaks dropped as the amount of clay mineral in the sample diminished. The 600°C endothermic peak of kaolin drops about 60°C and the 320°C endothermic peak of gibbsite drops about 30°C, as the amount of kaolin drops from 75 to 15 per cent.

RESULTS

pH Measurements

Histograms, Figs. 1 and 2, show the distribution of pH data in weathering profiles from granitic rocks and biotite gneiss respectively. Saprolite and saprock samples are not separated in these diagrams. Both saprolite histograms show a wide variation in pH without a significant peak. This is indicative of disequilibrium in which the primary rock-forming minerals are at various stages in their transformation to clay minerals. The details of this transformation have been reported for the biotite gneiss (Grant, 1964) and for some of the granitic rocks (Grant, 1963). Histograms of the B horizon, the red clay, show a strong maximum between pH 5 and 5.3, and a short range—from 4.3 to 5.6 in granites and 4.6 to 6.3 in the biotite gneiss. This is interpreted as an equilibrium condition in which kaolin is stable.

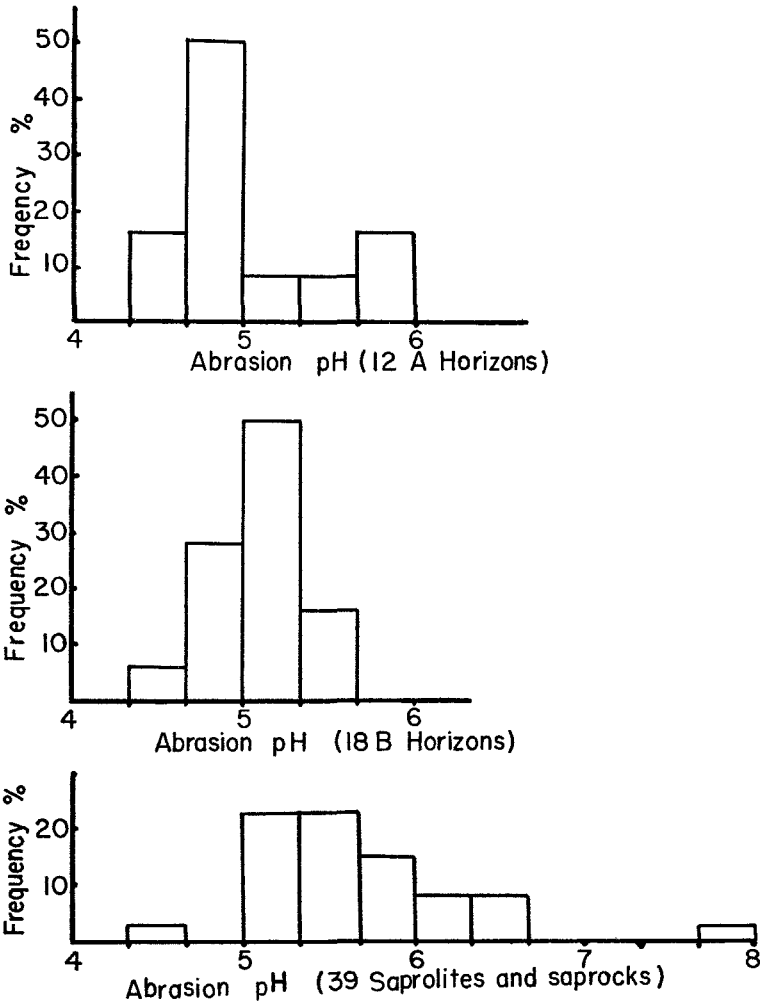


FIG. 1. Frequency per cent of abrasion pH values in the weathering profile of granitic rocks.

The A horizon, low in clay and containing organic matter, shows a less pronounced and more acid maximum than the B horizon and a greater spread of pH values. This again suggests a disequilibrium environment imposed upon the clay minerals by being mixed with the products of organic disintegration.

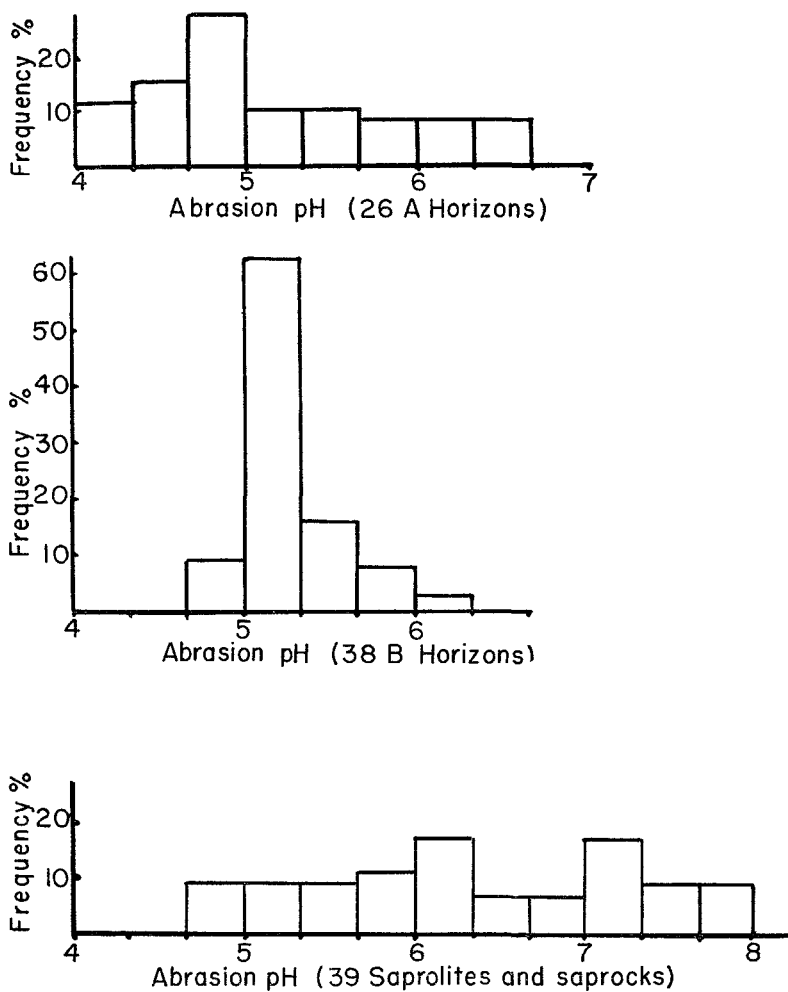


FIG. 2. Frequency per cent of abrasion pH values in the weathering profile of biotite gneiss.

Kaolin Distribution

The distribution of kaolin in the various horizons is shown in Fig. 3 for granitic rocks and in Fig. 4 for biotite gneiss. The various horizons are indicated by keying to maximums in the pH distributions shown in Fig. 1. These diagrams show that kaolin is most abundant in the B horizon for both granites and biotite gneiss and that the gneiss B horizon contains more kaolin than the corresponding granite. In both diagrams, the amount of

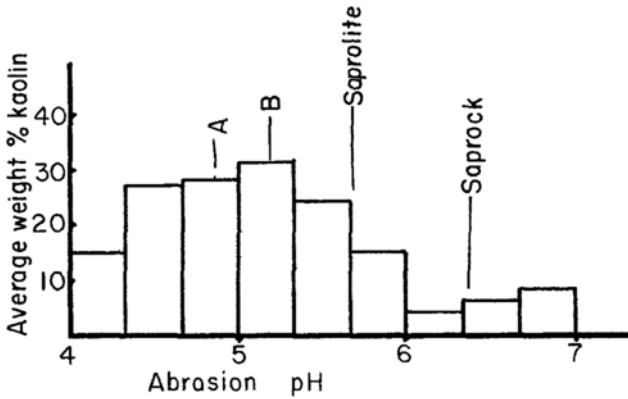


FIG. 3. Average weight per cent kaolin in granitic rocks as a function of pH, and the average pH of the various parts of the weathering profile.

kaolin declines toward both the acid and the basic conditions. Had these histograms been plotted on field identification of the various horizons, rather than pH, the difference in kaolin content between the A and the B horizons would have been much greater. This leaves a suggestion that pH is not the only factor involved. Fresh rock abrasion pH in both biotite gneiss and granites is greater than 9.

Gibbsite Distribution

Gibbsite was not measured directly, but as a proportion of the kaolin expressed as a percentage of the sum of the 320°C and 600°C endothermic peaks of gibbsite and kaolin respectively. The results of this are shown in

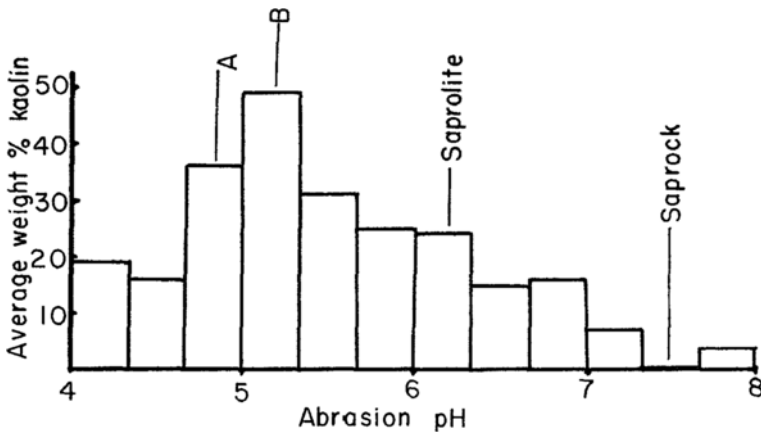


FIG. 4. Average weight per cent kaolin in biotite gneiss as a function of pH, and the average pH of the various parts of the weathering profile.

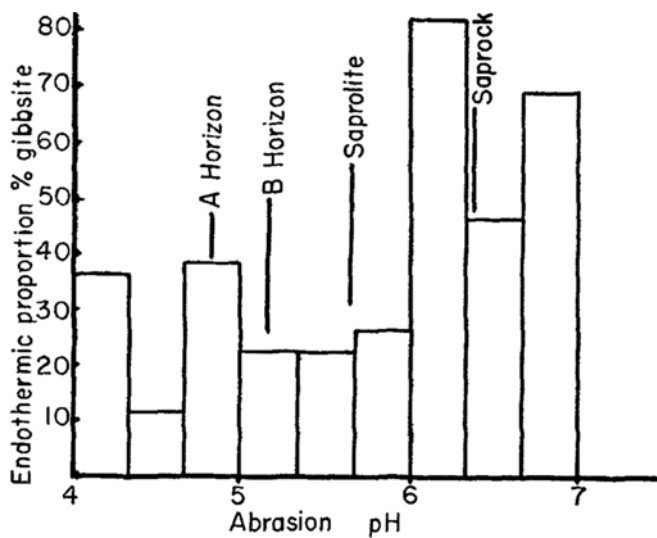


FIG. 5. Proportion per cent of the gibbsite endothermic peak as a function of pH in granitic rocks.

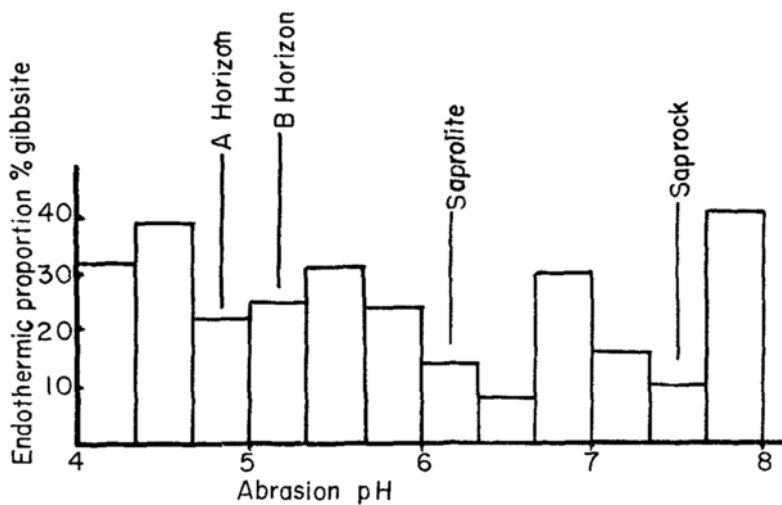


FIG. 6. Proportion per cent of the gibbsite endothermic peak as a function of pH in biotite gneiss.

Fig. 5 for granitic rocks and in Fig. 6 for the gneisses. Horizon pH values are taken from Fig. 1. The diagrams for both the granites and the biotite gneiss show high proportions of gibbsite at the acid and basic ends of the scale with lower proportions of gibbsite in the middle pH values. The secondary maximum in the biotite-gneiss diagram (Fig. 3b) between pH 5.3 and 5.6 is a persistent feature that does not occur in granitic rocks. Changes in gibbsite similar to these are shown in the data given by Van der Merwe and Haystek (1952, p. 384) for the surface horizons.

Kaolin Particle-Size Measurements

Particle-size measurements for each horizon in the weathering profiles are given in Table 1. They show that the particle size of kaolin increases in biotite gneiss from not subject to estimate in the fresh rock to a maximum equivalent spherical diameter of 61μ in the B horizon and then declines to an average of 13μ in the A horizon. The equivalent spherical diameter of kaolin in granitic rocks increases in the same way in the fresh rock to 42μ in saprolite then declines to an average of 12μ in the A horizon.

Individual profiles, where it was possible to measure changes in particle size as a function of depth, show essentially the same thing as the averages in Table 1 except that the depths at which the changes occur vary. For example, one profile showed a change in apparent size of 40μ in 3 ft, while a second profile showed a change of only 20μ . In general the kaolin particle size always increases with depth down to a zone in either the lower part of the B horizon or the upper part of the saprolite, then decreases in size and abundance to the fresh rock.

SUMMARY

1. The pH changes from 4.5 in the A horizon to over 9 in fresh rock.
2. The amount of kaolin increases from zero in fresh rock to a few per cent in saprock to a maximum of 40–70 per cent in the B horizon and then declines to between 10 and 20 per cent in the A horizon.
3. The proportion of gibbsite to kaolin shows a sharp increase in the saprock, declines in the saprolite and lower B horizon, and rises again in the upper B and A horizons.
4. The maximum equivalent spherical diameter of kaolin particles increases away from the fresh rock to a maximum in the lower B or upper saprolite horizon and then declines sharply in the A horizon.

CONCLUSIONS

1. The decline in maximum particle size in the A horizon is attributed to the solution of kaolin.
2. The increase in the proportion of gibbsite in the A horizon is also attributed to the solution of kaolin.

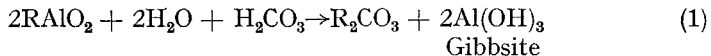
3. The increase in the amount of kaolin in the B horizon and the decline in the proportion of gibbsite are attributed to the reaction of alumina- and silica-bearing solutions derived from the A horizon to form new kaolin. This is also supported by the occasional occurrence of halloysite veins in the B horizon.

4. The high proportion of gibbsite to kaolin in the saprock and lower saprolite horizons is attributed to the early formation of gibbsite, probably in the earliest phases of feldspar weathering with an initial pH over 9. This is supported by observations of Carroll (1953, p. 91) who noted that one of the first signs of feldspar alteration was the formation of a little gibbsite.

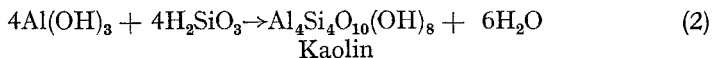
5. Kaolin is stable between approximately pH 4.5 and pH 8.5; it decomposes under more acid or more basic conditions. Keller *et al.* (1965) shows that halloysite is stable down to pH 3. This observation, coupled with the fact that pH appears not to be the sole factor in kaolin decomposition, leaves the possibility of organic acids decomposing the kaolin.

6. Genetically there are two kinds of kaolin, one derived from the decomposition of feldspar and the other formed in the B horizon from solutions derived from the A horizon.

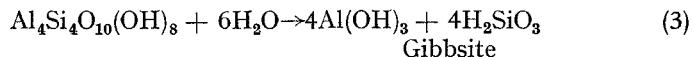
7. The equations believed best to describe the conditions are as follows. "R" is an alkali metal usually Na or K.



The transition from fresh rock to saprock; pH about 9.



The transition from saprock to saprolite changing gibbsite to kaolin; pH below 8. Also represents the reconstitution of kaolin in the B horizon from material decomposed in the A horizon.



The decomposition of kaolin in the A horizon under acid conditions; pH probably less than 4.5.

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