

WEATHERING OF STONE MOUNTAIN GRANITE

by

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ABSTRACT

The weathering of Stone Mountain Granite (adamellite) forms kaolinite, endellite, allophane and gibbsite of which kaolinite is the most stable. Bulk density ranges from 2.65 in fresh rock to a minimum of 1.48 in saprolite. It is a good index of weathering. Abrasion pH ranges from 5.0 in saprolite to 9.3 in fresh rock, and is directly related to bulk density and the amount of clay mineral. Among the original minerals, biotite is least stable, followed by oligoclase. Residual microcline fragments occur at the base of the B horizon indicating that it is not completely weathered. Muscovite weathers slightly and quartz appears quite stable.

Evidence shows that solution and reconstitution is necessary in the formation of some if not all clay minerals. This is particularly evident in the formation of endellite veins.

Expansion of the rock in the early phases of weathering occurs but does not produce a significant increase in volume.

INTRODUCTION

Stone Mountain is situated 13 miles east of Atlanta, Georgia in the center of the Piedmont. The U.S. Geological Survey, Stone Mountain Quadrangle map (1956) shows local relief to be about 100 ft, with an elevation of 900 ft above sea level. The mountain itself is a rounded elongate monadnock rising 800 ft above the surrounding area with an elevation of 1683 ft.

The rock is an admellite or quartz monzonite (Herrmann, 1958, p. 29). The average composition of the rock in the area studied is given in Table 1. Data used in Table 1 are from Herrman (1958, p. 31) and Grant (1962, p. 8).

The climate is warm and moist, modified somewhat by the altitude. The average annual precipitation is 47.58". However, variations in rainfall are considerable. The average July temperature is 78.5°F (26°C) and for January is 44.0°F (6.6°C) (Mindling, 1941).

The average pH of rainwater from 55 storms taken in all seasons of the year is 5.0. The average temperature of the water is 15°C.

PROCEDURES

Sampling was confined to a gently undulating area of about two square miles immediately north of the mountain. A total of 42 samples were taken from roadcuts and recent excavations. All samples came from moderately

well-drained places and were confined to the zone between fresh rock and the base of the soil B horizon.

Mineral identification was based on standard petrographic techniques using thin sections and oil immersion. Differential thermal analysis was used to confirm and support identifications.

TABLE 1.—AVERAGE OF 7 MODAL ANALYSES OF FRESH ROCK*

	Volume %	Average, Deviation, %
Quartz	30.0	1.7
Oligoclase	32.0	3.2
Microcline	28.5	2.5
Muscovite	8.4	2.7
Biotite	1.1	0.4
	100.0	

* Does not include various accessory minerals.

Quantitative work was done by differential thermal analysis and the point count method. The standards for differential thermal analysis were prepared by removing all of the clay from the granite residuum by gentle wet grinding and repeated washing. Then varying known amounts of commercial Georgia kaolin were added and mixed with the clayless residuum to form a series of samples. These were run in the differential thermal analysis apparatus and curves prepared. The amplitude of the 580°C endothermal peaks was plotted against weight percent kaolin. The resulting curve is nearly a straight line similar to that shown by Kerr and Kulp (1948, p. 418). The curve was used to determine the weight percent kaolin in raw, damp saprolite samples. Results obtained by using this curve are in fair agreement with data obtained by point count modal analysis. Vertical bars shown in the kaolin minerals area of Fig. 1 compare the amount of kaolin, converted to volume per cent, obtained by the differential thermal analysis method with the kaolin abundance from the point counts. It is difficult to state the accuracy of the measurements. In general, it seems the accuracy decreases as decomposition of the rock increases. However, the overall agreement of data by various approaches indicates the results are reasonable.

Bulk Density

Bulk density determinations were made on samples carefully collected to preserve the saprolite fabric. Saprolites with bulk densities less than 2 are so friable that handling without disintegration is difficult. The samples, weighing from 30 to 100 grams, were air dried and sprayed with "Krylon"* to prevent absorption of water and disintegration during density measurement. Bulk density is a good index of the degree of weathering. The rock has a decreasing degree of coherence down to a density of 2. Below 2 it crumbles easily. Figures

* Krylon, Inc., Norristown, Pa.

2 and 3 show the variation of pH and weight per cent kaolin minerals as a function of bulk density. Density ranges from 2.65 in fresh rock down to 1.48 in completely weathered saprolite.

Abrasion pH

Abrasion pH determination is a modification of the technique of Stevens and Carron (1948). The method used consists of vigorously grinding about 20 grams of raw saprolite with an equal amount of distilled water in an agate

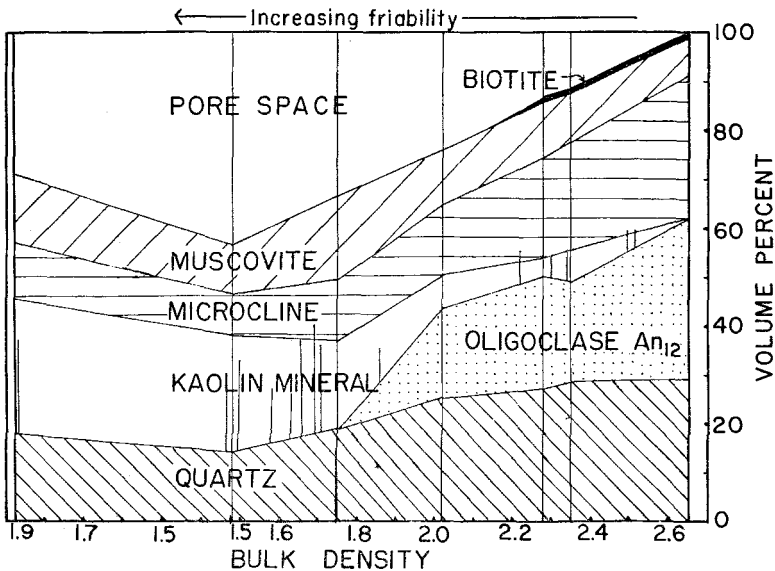


FIGURE 1.—Variation of mineral composition with degree of weathering. Vertical bars in the kaolin minerals area show kaolin amount by DTA.

mortar for 2½ minutes. The quantities of saprolite and water are not critical but time is important because extended grinding will raise the pH of slurries from partially weathered rock. Electrodes from a pH meter are allowed to stand in the slurry for about 2 minutes, then the pH is measured. Reproducibility of results is within 0.3 pH units. The range of values is from 5.0 in completely weathered rock to 9.3 in fresh rock.

Results of this empirical procedure are in agreement with published data on natural waters. A pH range from 5.8 to 7 is given for deep-well water in granites of North Carolina (LeGrand, 1958, p. 184). Such a range would be expected from granite with bulk densities of 1.9 to 2.5 (Fig. 2), and a percentage of kaolin mineral ranging from roughly 2 to 9 per cent (Fig. 3). The pH of spring waters in granite range from 5.4 to 5.8 (LeGrand, 1958, p. 182). These figures correspond to saprolites with bulk densities of roughly 1.5 to 1.6 and kaolin mineral content of roughly 20 to 30 per cent (Figs. 2 and 3). Values of

pH much higher than 7 are not likely to be found in circulating ground water because of the low permeability of fresher rock.

Thin Sections

Thin sections show two significant mineral relationships. Microscopic mineral filled cracks or veins which transect residual minerals, occur in the early phases of weathering. Plate 1 is a photomicrograph of several of these veins. They are interpreted as indicating two conditions. First, that there is some expansion in the early stages of weathering to open the cracks. Second,

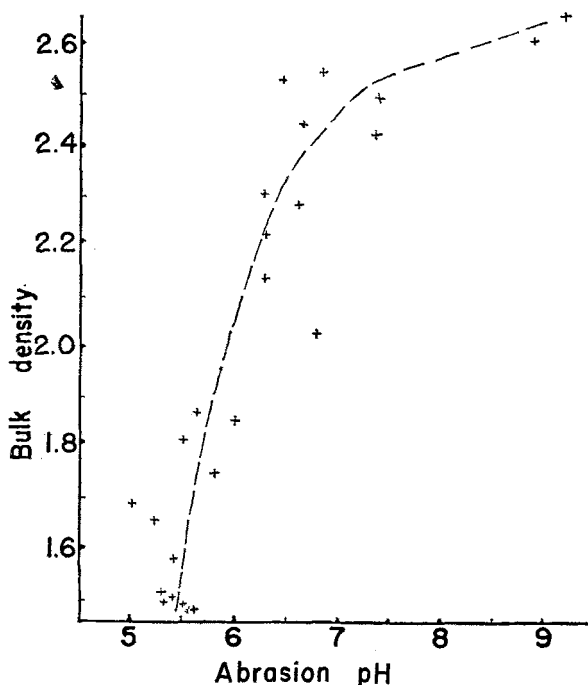


FIGURE 2.—The rate of decrease in pH with the decrease of bulk density as degree of weathering increases.

that solution of weathering products occurs in order to fill them. The second conclusion is supported by the occurrence of endellite veins shown in Plate 2. In order for these to form there must have been both solution and migration of silica and alumina. Migration of silica is also suggested by the presence of hyalite on joint faces in some quarries. The second microscopic relationship is the occurrence of mineral-filled, V-shaped fractures in plagioclase, in addition to the openings along cleavages. The V-shape is interpreted as a wedging apart of a grain by expansion. Vein fillings are mainly isotropic but some birefringent spots occur. Some filling has been identified as allophane by both

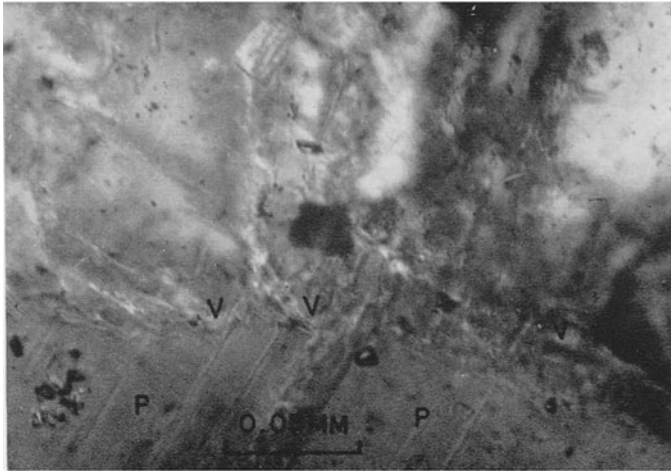


PLATE 1.—Photomicrograph showing veins (V) of weathering product in plagioclase (P). Crossed nicols and quartz wedge.

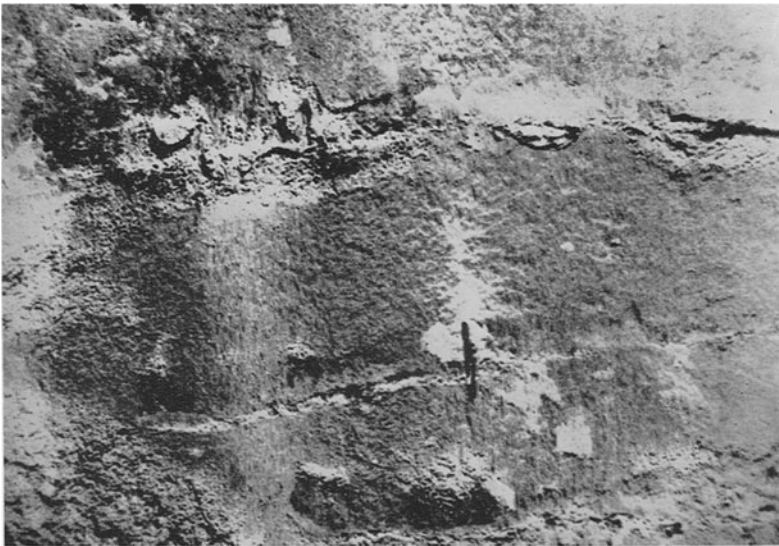


PLATE 2.—Endellite veins in granite saprolite. The pen is $5\frac{1}{2}$ in. long.

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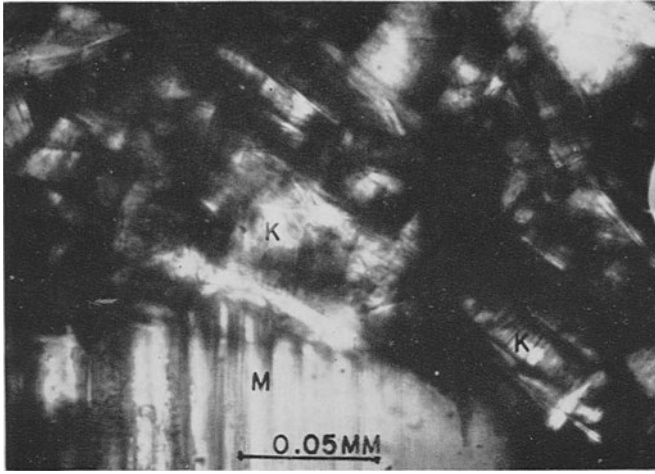


PLATE 3.—Photomicrograph of microcline (M) and kaolin (K) in saprolite.
Crossed nicols.

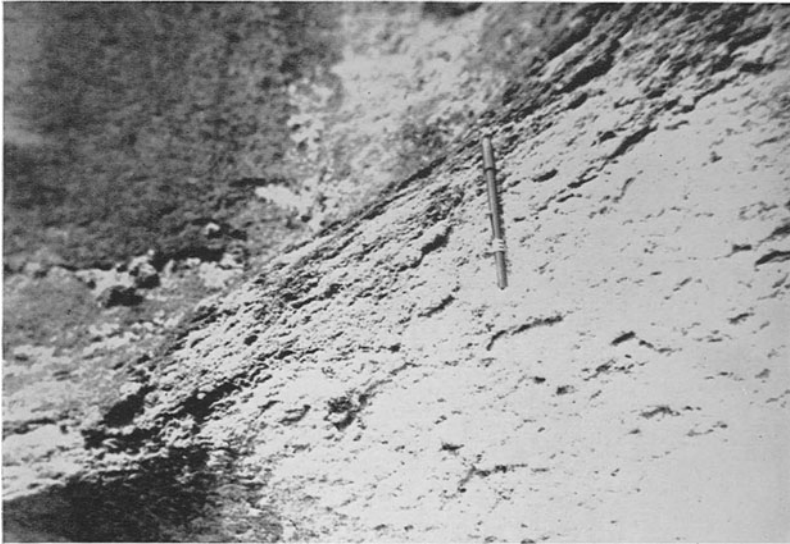


PLATE 4.—Concentric shells on the edge of a residual boulder. The pen
is $5\frac{1}{4}$ in. long.

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refractive index, and differential thermal analysis (Table 2 and Fig. 4). The allophane curve is similar to the curve published by Sudo and Takahashi (1955), except for the small endothermic peak at 540°C and the gibbsite peak at 320°C. Furthermore, some of the fragments of allophane show the imprint of feldspar cleavage. Endellite occurs in many of these rocks, hence it is possible that it also occurs in the micro-veins.

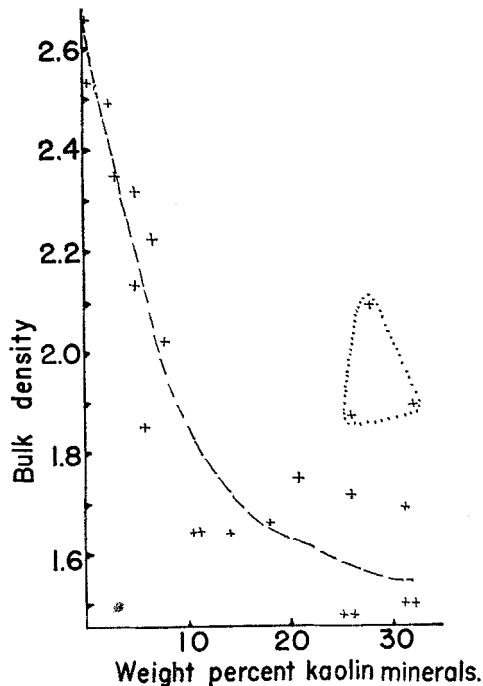


FIGURE 3.—The relation between the bulk density and the abundance of kaolin minerals as determined by thermal analysis. Circled area contains iron stained samples from close to the B horizon.

The alteration process for microcline is uncertain because it is never completely weathered and its associates are quite variable. Plate 3 shows microcline in contact with kaolinite.

Kaolinite occurs as aggregates or single books, and is the dominant end product of weathering. Endellite is definitely minor. It replaces plagioclase in a pegmatite in the contact zone between the country rock and the granite. Table 2 gives the optical data and Fig. 4 the differential thermal analysis of these minerals.

A micaceous mineral becomes abundant in some of the most weathered saprolites. Differential thermal analysis of the micaceous fraction shows an endothermic peak at 560°C which is probably kaolinite and a second peak at

TABLE 2.—MICROSCOPIC AND OPTICAL CHARACTERISTICS OF MINERALS*

	N_x	N_y	Remarks
Kaolinite	1.555	1.565	Books and worms from saprolite. $2V$ less than 20° , optically negative.
Endellite	1.528		Waxy, buff mineral from veins. Isotropic.
Endellite	1.529		From feldspar in pegmatite contact zone just outside granite. Isotropic.
Endellite	1.530		Irregular aggregates from saprolite. Usually contains birefringent specks.
Allophane	1.485		Irregular transparent particles from weathered rock. Refractive index ranges from 1.480–1.490.
Hyalite	1.451		Rare, occurs as coating on hard rock in quarries.

* All refractive indices ± 002 . Unless noted otherwise.

620°C . Because of the number of micaceous minerals present and their various stages of decomposition the mineral causing the 620°C peak was not isolated. Figure 4 shows the differential thermal analysis curve of this fraction. The presence of muscovite-like minerals is reported in other studies (Sand and Bates, 1953, p. 358).

Muscovite appears to alter directly to kaolinite.

INTERPRETATIONS

Weathering begins with meteoric water percolating downward in three sets of vertical joints of tectonic origin and horizontally along sheet joints which according to Hopson (1958) are of dilation origin. The movement of water along these fractures is substantiated by LeGrand (1949), who says that sheet joints are the principal channels for water in granitic rocks; and that they are known to occur at depths up to 150 ft. Thus, the initial condition may be visualized as rectangular blocks of rock surrounded by water bearing fractures. Water soaks into the rock and the alteration process begins. Strongly alkaline conditions are indicated by the abrasion pH of fresh rock which is 9.3 (Fig. 1). This is alkaline enough to materially aid in the mobilization of silica (Krauskopf, 1956, p. 23). Alumina is also soluble at this pH (Correns, 1949, p. 210). Allophane, gibbsite, endellite, and kaolinite all occur in minor amounts. With continued weathering the core or harder part of the original block takes on a pillow-shape with very poorly developed concentric shells on the outside edges (Plate 4). The shells suggest a slight expansion of the rock during early hydration (Blackwelder, 1925, p. 795). This stage of weathering produces the following minerals and mineral changes; kaolinite is dominant; allophane and gibbsite have disappeared, and so has all of the plagioclase. The final stage of weathering produces a friable mass of white saprolite whose minerals are kaolinite, minor endellite, quartz, muscovite and microcline. This condition

continues with minor changes in mineral proportions up to the base of the B soil horizon, where the original rock texture gives way to a soil texture, iron staining appears, and the bulk density rises. The points circled on Fig. 3

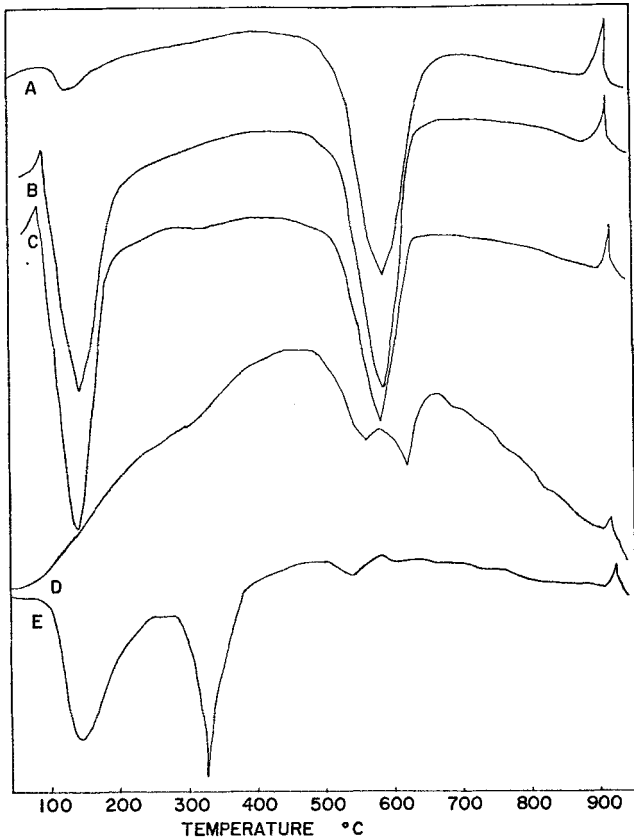


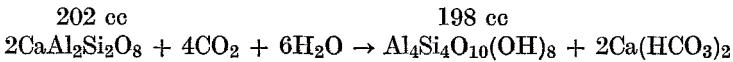
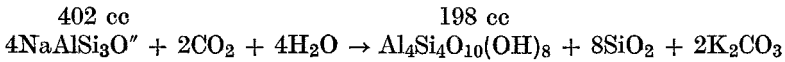
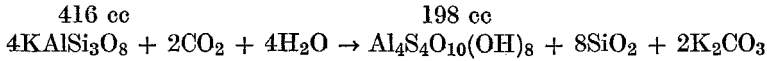
FIGURE 4.—Thermograms of various minerals produced by weathering.

- A. Kaolinite from elutriated saprolite.
- B. Buff, vein endellite.
- C. Endellite derived from pegmatite feldspar.
- D. Micaceous fraction.
- E. Allophane, gibbsite and minor kaolinite elutriated from partly weathered rock.

represent samples taken from iron stained material at or near the base of the B horizon. The left hand side of Fig. 1 shows a sample from the base of the B horizon whose bulk density has risen to 1.88. These facts are summarized in Fig. 1.

Preservation of primary structures in the saprolite indicates that no large

volume changes have occurred. Assuming the weathering process proceeds stoichiometrically and that the stable end product is kaolinite; the following equations are written:



From these equations the volume lost on weathering amounts to 51 per cent for albite, 52 per cent for microcline and 2 per cent for anorthite. Hence, if the rock volume remains constant during weathering then, using the average composition from Table 1, a rock with all of its feldspar weathered should have a bulk density of 1.90. Actual bulk density of saprolite with some residual microcline shows a minimum of 1.48. Thus, some other factor must be considered. Calculating the theoretical kaolin content from these equations and comparing it to the actual kaolin content shows variable discrepancies which are always less than the theoretical amount. The possible conclusions are; that an increase in volume or a loss in silica and/or alumina in solution has occurred. Loss in solution is supported by the occurrence of endellite veins and also by the presence of gibbsite and rarely hyalite. This is also in agreement with Correns and v. Engelhart (1938), who show experimentally that potash feldspar goes into true solution. There is also evidence of some expansion, probably due to hydration, in the early stages of weathering as evidenced by concentric shells and formation of micro-veins in the earlier stages of weathering (Plates 1 and 4). Solution seems to be the strongest agent.

CONCLUSIONS

1. Bulk density is a good weathering index.
2. Abrasion pH correlates well with known pHs of natural waters and is high enough in the initial stages of weathering to mobilize silica and alumina.
3. Kaolin, the stable end product, can form in an environment whose abrasion pH ranges from 5.2 to at least 7.3.
4. Some alumina and silica are carried away in true solution.
5. The major weathering products are kaolinite, endellite, allophane and gibbsite.
6. Secondary white mica is probably formed during the later stages of weathering.
7. Allophane is one of the earliest formed new minerals.
8. Minor expansion of the rock, probably as a result of early hydration, occurs.

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