

DEPTH AND PARTICLE SIZE DISTRIBUTIONS OF TALC IN A VIRGINIA PIEDMONT ULTISOL

Key Words—Iron oxides, Saprolite, Soil, Talc, X-ray powder diffraction.

Talc is a constituent of many hydrothermally altered ultramafic rocks and thermally metamorphosed dolomites (Deer *et al.*, 1962), but it has rarely been detected in soil profiles (Zelazny and Calhoun, 1977). Talc was detected in soils directly overlying a talc deposit in southeastern Pennsylvania (Blount and Spohn, 1982), along with serpentine, chlorite, illite, tremolite, plagioclase, quartz, and interstratified phyllosilicates. The mineralogy of the latter soils is atypical of residual humid region soils, which are commonly high in kaolinite and other secondary minerals associated with a leaching and acidic environment.

The scarcity of talc in soils has been attributed to instability in a leaching environment (Reiche, 1943); however, we have detected this mineral in a highly leached Virginia Piedmont Ultisol formed over deep saprolite. This study reports the depth and particle-size distribution of talc in this soil profile which, by traditional concepts of mineral stability, is an unlikely environment for such a phase.

MATERIALS AND METHODS

The soil profile studied is a clayey, oxidic, thermic Typic Hapludult from Pittsylvania County, Virginia. It formed in saprolite of the Rich Acres Formation, which ranges from metadiorite to metamorphosed ultramafic rock (Henika and Thayer, 1977). Talc has been found in the latter rocks in fibrous masses between olivine crystals.

Samples from all genetic horizons were air-dried, ground, and sieved to remove coarse fragments. The particle size was determined by pipette analysis (Day, 1965), and free Fe was determined by citrate-dithionite-bicarbonate (CDB) extraction (Mehra and Jackson, 1960). Exchangeable Ca, Mg, and K were determined by extraction with 1 N NH_4OAc at pH 7, extractable acidity by back titration of unreacted extracts of $\text{BaCl}_2\text{-TEA}$ at pH 8.2, and exchangeable Al by 1 N KCl extraction.

Samples for X-ray powder diffraction (XRD), thermal, and infrared (IR) analyses were pretreated with citrate-dithionite to remove oxide coatings. Sand was separated by wet sieving, and silt and clay were separated by centrifugation with subsequent decantation using dilute Na_2CO_3 adjusted to pH 9.5 as a dispersant.

Oriented mounts of the clay were prepared by depositing approximately 250 mg in suspension on a ceramic tile mounted on a suction apparatus and washing the clay until it was free of salts. Oriented mounts of silt and ground sand were prepared by tightly packing the powder into shallow, recessed holders. Semiran-

dom mounts of selected samples were prepared by loosely packing the powder into the recessed holders. XRD patterns of samples heated to 100° and 550°C were obtained using $\text{CuK}\alpha$ radiation and a Diano 800 X-ray diffractometer equipped with a graphite crystal monochromator and a LSI-11 computer. Samples were scanned at $2^\circ 2\theta/\text{min}$.

Differential scanning calorimetric (DSC) and thermal gravimetric (TGA) analyses were conducted using a DuPont 1090 Thermal Analyzer. For DSC, aliquots of clay, silt, and ground sand from each horizon were heated from 50° to a maximum of 625°C in a N_2 atmosphere at a rate of 50°C/min. For TGA, selected samples were heated from 50° to 1200°C at a rate of 10°C/min. Kaolinite and gibbsite were quantified by mass-equivalent calibration of endothermic DSC peak areas using a poorly crystalline Georgia kaolinite and Reynolds synthetic gibbsite (RH-31F) as standards.

IR analysis was conducted on a standard talc sample and on selected samples using a Perkin-Elmer 283 IR spectrophotometer. Samples were prepared by heating them to 110° or 550°C, dispersing them in solid KBr, and pelletizing them at high pressure.

Talc was quantitatively estimated using the relationship:

$$I_t/I_k = C(M_t/M_k),$$

where I_t and I_k are integrated intensities of the 9.4- and 7.2-Å XRD peaks of talc and kaolinite, respectively; M_t and M_k are the masses of talc and kaolinite, respectively; and C is a constant determined empirically as the slope of I_t/I_k vs. M_t/M_k for known mixtures of standard talc and kaolinite. The value M_k for the samples studied was taken as the mass percentage of kaolinite as determined from DSC calibration.

Sand grains were examined using a Zeiss petrographic microscope and an American Optical binocular dissecting microscope. Fe oxide-cemented aggregates and lithic fragments were hand-segregated from the sand fraction with tweezers and examined by XRD and DSC.

RESULTS

The presence of talc was indicated by the 9.4-Å (002) and 3.12-Å (006) XRD peaks (Figures 1 and 2) that persisted at 550°C (Figure 2). The 060 reflection at 1.53 Å was also present in the pattern of a random mount (Figure 2). TGA and IR corroborate the presence of talc. The weight loss inflection at 900°C on the TGA pattern (Figure 3) is diagnostic of talc, as is the OH-stretching IR absorption band at 3679 cm^{-1} (Figure 4). The presence of kaolinite is indicated by 7.2-Å and

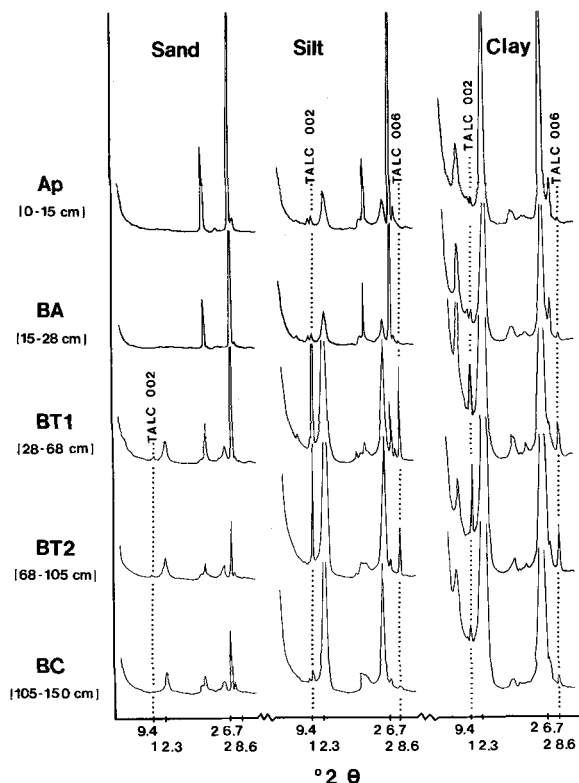


Figure 1. X-ray powder diffraction patterns for oriented mounts of clay, silt, and ground sand fractions from each horizon.

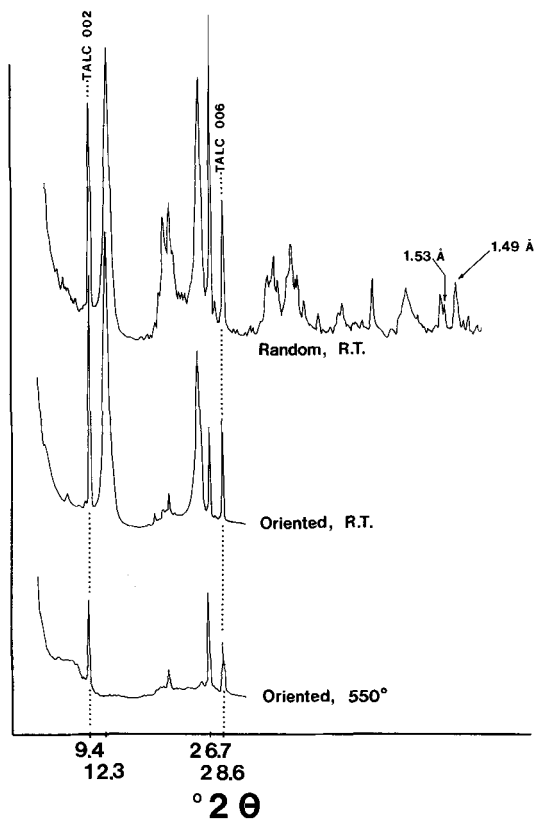


Figure 2. X-ray powder diffraction patterns of the Bt1 silt fractions for random and oriented mounts at room temperature (RT) and for an oriented mount after heating to 550°C for 9 hr.

3.5-Å XRD peaks, by the weight loss between 450° and 650°C (Figure 3), and by the OH-stretching IR absorption bands at 3696 and 3623 cm^{-1} (Figure 4).

Talc is detectable by XRD in the silt and clay fractions of all horizons and in the sand fraction of the Bt1 and Bt2 horizons (Figure 1). Other minerals present are quartz (4.26 and 3.33 Å), kaolinite (7.20 and 3.57 Å); hydroxy-interlayered vermiculite (14 Å); mica (10.08 Å); chlorite (14 Å); feldspar (3.25 Å); ilmenite and magnetite (peaks not shown); and gibbsite (detected by DSC). Trace amounts of translucent heavy minerals were detected in the sand by petrographic microscopy.

Quantitative analysis of talc, kaolinite, and gibbsite (Table 1) shows kaolinite to dominate the clay fraction and to be present in significant amounts in the silt and sand fraction of lower horizons. Kaolinite and gibbsite characteristically increase and decrease, respectively, with depth. Talc, however, is concentrated in the Bt1 and Bt2 horizons for all size fractions.

Talc is not indicated by XRD of the whole sand fraction for Ap and BA horizons (Figure 1); however, it is detectable in Fe oxide-cemented aggregates hand-segregated from the sand fraction of these horizons

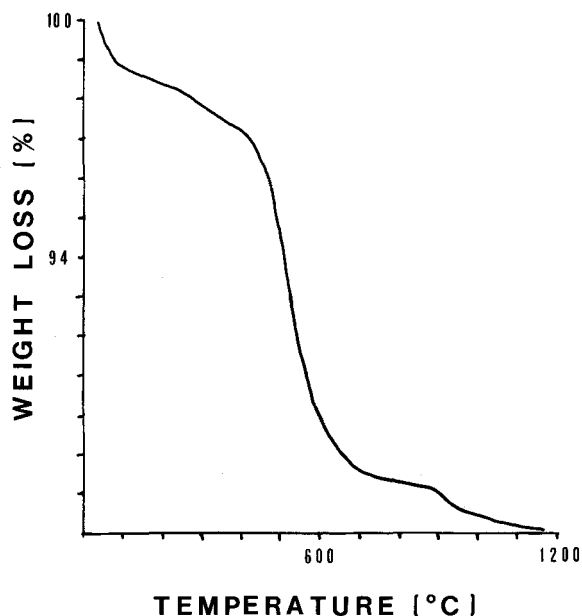


Figure 3. Thermal gravimetric analysis of the Bt1 silt fraction.

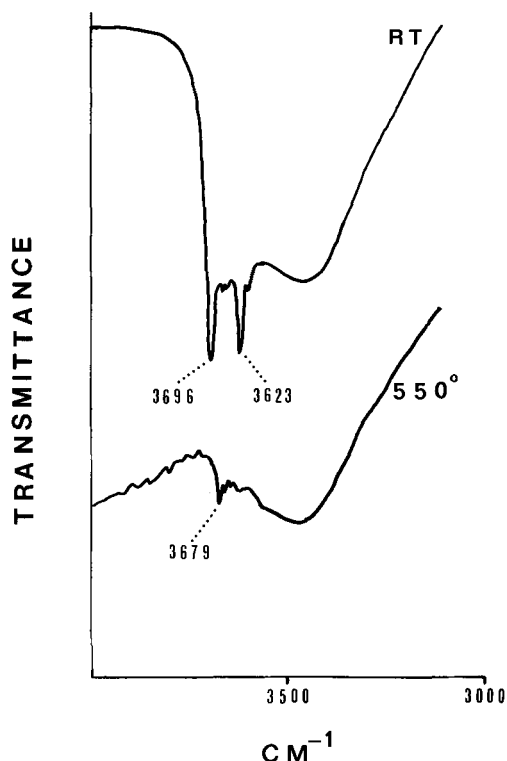


Figure 4. Infrared analysis of the Bt1 silt fraction at room temperature (RT) and after heating to 550°C for 9 hr.

(Table 2). These aggregates, which are also present in the Bt1 and Bt2 horizons, have no discernible structure and may be of pedogenetic origin. They contain, in addition to talc, appreciable quantities of goethite, quartz, feldspar, and kaolinite. The Bt2 horizon also contains soft, fine-grained lithic fragments with schistose structure. These fragments contain more talc than any other isolated soil component (Table 2). They also contain goethite, kaolinite, and minor amounts of other minerals.

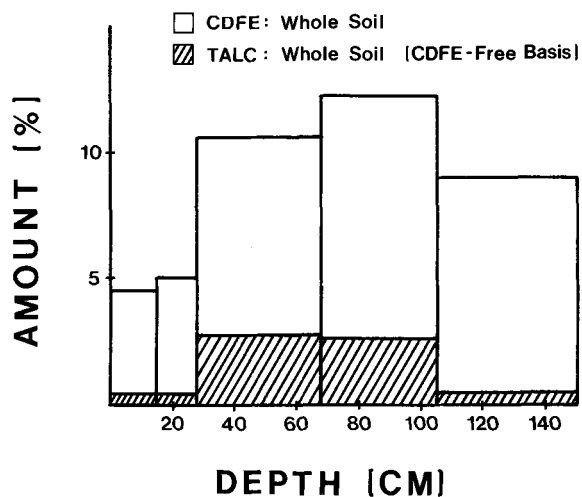


Figure 5. Citrate-dithionite-bicarbonate-extractable Fe (CDFE) and talc content on a whole soil basis at horizon depth intervals.

Table 2. Estimated talc content of selected components from the soil profile studied.

Horizon	Depth (cm)	Talc content (%)		
		Whole soil	Fe oxide ¹ -cemented aggregates	Lithic fragments
Ap	0-15	trace	2	— ²
Bt1	25-68	3	3	—
Bt2	68-105	3	4	17

¹ Aggregates were crushed and re-treated with CDB prior to XRD and DSC analyses.

² Lithic fragments were too few to analyze in upper horizons.

The pH and exchangeable Ca, Mg, and K are low below a depth of 25 cm, where the influence of liming is less intense (Table 3). The BaCl₂-TEA extractable acidity and KCl-extractable Al increase and base-saturation percentage decreases with depth.

Table 1. Estimated talc (T), kaolinite (K), and gibbsite (G) content (%) for CDB-treated sand, silt, and clay fractions.

Horizon	Depth (cm)	Sand		Silt			Clay		
		T	K	T	K	G	T	K	G
Ap	0-15	Tr ¹	Tr	1	18	Tr	Tr	65	2
BA	15-25	Tr	Tr	1	16	Tr	Tr	67	2
Bt1	25-68	Tr	18	7	36	Tr	1	74	1
Bt2	68-105	1	29	5	57	ND ²	1	70	Tr
BC	105-150	Tr	36	1	66	ND	Tr	79	Tr

¹ Tr = trace.

² ND = none detected.

Table 3. Chemical properties of the samples examined.

Horizon	Depth (cm)	pH	Exchangeable bases (meq/100 g)			BaCl-TEA acidity (meq/100 g)	KCl-Al (meq/100 g)	Base saturation (%)
			Ca	Mg	K			
Ap	0-15	5.6	3.9	1.8	0.2	7.3	0.1	44.8
BA	15-25	6.1	4.4	2.0	0.1	5.4	0.1	54.8
Bt1	25-68	5.1	2.6	1.6	0.2	11.7	0.4	27.1
Bt2	68-105	4.9	0.1	0.5	0.2	10.1	2.9	7.5
BC	105-150	5.1	0.2	0.4	0.1	10.5	4.0	6.4

DISCUSSION

The mineralogy of this soil, with the exception of talc, is typical of ultisols with red subsoils on broad, stable summits of the Virginia Piedmont. These soils are considered to be "old" by geomorphological inference and by indications of prolonged weathering, such as deep saprolite, depletion of primary minerals and bases, low pH and permanent charge CEC, and advanced subsoil development due to illuvial accumulation of clay and Fe oxide (Blume and Schwertmann, 1969).

A possible explanation for the persistence of talc in such a highly weathered, acidic soil is that the talc crystallites are protected from soil solution by coatings of Fe oxides liberated through weathering of Fe-rich minerals. Illuvial Fe oxide coatings may have helped to preserve talc crystallites. The citrate-dithionite-bicarbonate-extractable Fe (CDFE) in this profile is very high relative to samples from other Virginia Piedmont soils, and is highest in the subsoil where the talc concentration is also highest (Figure 5).

Talc is further associated with Fe oxides in that it is imbedded in Fe oxide-cemented aggregates and in lithic fragments which have likely been preserved by Fe oxide cementation. High talc concentrations in these lithic fragments (Table 2) confirm that this mineral is inherited from the parent material. Talc has even persisted in Fe oxide aggregates from the Ap horizon, where weathering is most intense, demonstrating that the Fe oxide matrix protected the talc not only from chemical weathering, but from the physical stresses of wetting-drying, freezing-thawing, etc., that are intense in the upper profile.

Verification of the link between Fe oxides and talc preservation requires the study of more talc-containing profiles to check for relic lithologic influences on mineral distribution that might fortuitously correspond to pedogenetic Fe oxide distribution. Further study may also show that other minerals susceptible to acid dissolution are preserved in humid region soils by Fe oxides.

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Department of Agronomy
Virginia Polytechnic Institute
and State University
Blacksburg, Virginia 24061

WILLIE G. HARRIS
LUCIAN W. ZELAZNY
JAMES C. BAKER

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