KAOLINITE FROM THE TERMINAL MORAINE OF STATEN ISLAND

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Isolated patches of white clay occurring in the terminal moraine of Long Island, Staten Island, and southern New Jersey have been mentioned in a number of geologic descriptions. Such an occurrence was recently encountered during excavation for a building site and samples were submitted to the mineralogical laboratory of Columbia University for identification by Messrs. Schoonmaker and Kirkman. Examination proved the clay to be composed essentially of kaolinite and muscovite. In view of the unusual occurrence, however, the clay appears to merit description. Recent studies[1] of clay minerals suggest that a review of a number of the early described occurrences of "kaolin" would be worth while. This paper is submitted as a part of such a program.

The clay outcrops along the west bank of a small creek about one-half mile southwest of Princess Bay Station on the Staten Island Railroad. The locality lies 100 yards north of Hylan Boulevard, and may be reached by following the west bank of the creek from the beginning of the west approach of the creek bridge on the boulevard. The creek cuts through the terminal moraine at this point and flows southeast into the head of Princess Bay, on the south side of Staten Island. (*Staten Island sheet, U.S.G.S. topographic map.*)

The excavation in which the clay was encountered penetrates the glacial till of the terminal moraine to a depth of thirty feet. The material overlying the clay is typical till of the type peculiar to the Staten Island section of the terminal moraine. It consists of loosely consolidated clay studded with boulders of variable size and is made up of a heterogeneous assortment of materials. The white clay occurs at the bottom of the excavation (Fig. 1).

The clay varies from a fraction of an inch to a foot in thickness

[1] Ross, Clarence S. and Kerr, Paul F., Dickite a kaolin mineral: *Amer. Min.*, vol. **15**, No. 1, Jan. 1930, pp. 34–39. Kerr, Paul F., Kaolinite from a Brooklyn subway tunnel: *Amer. Min.*, vol. **15**, No. 4, Apr. 1930, pp. 144–158. Ross, Clarence S. and Kerr, Paul F., The Kaolin minerals: *Jour. Amer. Ceram. Soc.*, vol. **13**, No. 3, Mar. 1930, pp. 151–160, The Kaolin Minerals: *U.S. Geol. Surv., Prof. Paper*, **165E**, pp. 151–180, 1931.

and in some places consists of a few thin seams an eighth of an inch thick interstratified with red sandy shale and grit. The material resembles white clay occurring near the base of the Raritan formation of the Cretaceous. When moist it has a soapy feeling and forms a closely compact layer. It is white in color with a slight tint of cream and contains numerous micaceous particles. Soft

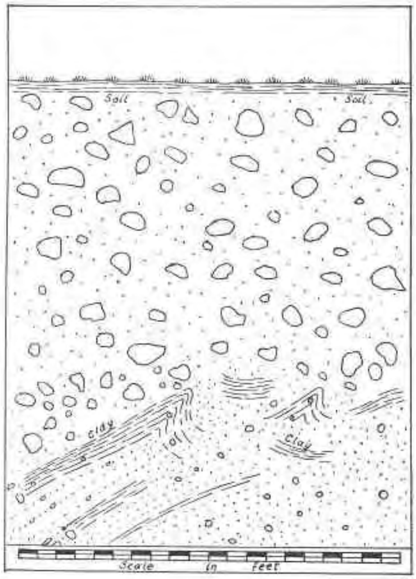

FIG. 1. Diagram illustrating the occurrence of kaolinite clay and sand beneath glacial till of the terminal moraine.

black carbonaceous material is in contact with the clay in a few places.

The exposure appears in irregular masses distributed over about ten feet in areal extent. The clay layers are decidedly irregular in stratification, are deformed and also are broken. In addition, they present the appearance of having been "plucked" loose from underlying strata and of having been transported a short distance from their original occurrence. Pockets of fine sand and also several irregular masses of gravel occur beneath the clay. These were uncovered by digging down several feet below the bottom of the excavation. A four-inch bed of red shale is also stratified in part parallel to the clay. Scattered through the white clay are isolated pebbles composed of various sorts of rocks which stand out in marked contrast to the white clay which surrounds them. Thin lenses of sand likewise occur in the clay mass.

Clays Deformed and Transported when Terminal Moraine was Formed

Geologists have recognized for some time that the ice sheet which formed the terminal moraine along Long Island,[2] Staten Island[3] and in New Jersey[4] deformed and also transported blocks of clay belonging to the underlying Cretaceous strata. Merrill first called attention to this action in 1886. In a discussion of the geology of Long Island he stated:

> We find the stratified gravels, sands and clays upheaved by the lateral pressure of the ice sheet and thrown into a series of marked folds at right angles to the line of glacial advance.

Hollick studied the phenomenon carefully and in describing the geology of Staten Island wrote as follows:

> Throughout the morainal and stratified drift deposits . . . masses of clay or 'kaolin,' sometimes incoherent, sometimes more or less hardened by the infiltration and oxidation of iron, are prominent constituents. They are especially abundant in the morainal accumulations at Tottenville, Princess Bay and Arrochar. It is evident that where such material occurs . . . it represents masses and fragments which were eroded from strata . . . and carried forward either by the advancing ice front or by streams from the melting glacier.

Microscopic Examination

The washed clay is made up of fine matted kaolinite mixed with minute fragments of mica and feldspar.

The grains are so small that optical determinations are accomplished with some difficulty. The unwashed clay is highly impure.

Indices of refraction of the kaolinite as determined by the immersion method are n_γ 1.565($\pm$.003) and n_α 1.560($\pm$.003). The double refraction is about .006.

[2] Merrill, F. J. H., On the geology of Long Island: *Ann. N. Y. Acad. Sci.*, iii, **1886**, pp. 341–364.

[3] Hollick, Arthur, Dislocations in certain portions of the Atlantic Coastal Plain strata and their probable causes: *Trans. N. Y. Acad. Sci.*, vol. **14,** Oct. 1894, pp. 8–20.

Hollick, Arthur, Cretaceous deposits of Staten Island: *U.S.G.S.*, Folio **83, 1902**, p. 10.

[4] Ries, H., Kümmel, H. B. and Knapp, G. N., The clays and clay Industry of New Jersey: *Geol. Surv. New Jersey*, vol. **VI.**

Impurities identified beneath the microscope in the washed clay included muscovite, plagioclase, rutile, and hematite, together with traces of quartz and orthoclase. Muscovite and plagioclase were noted in sufficient quantity to suggest a recast of the chemical analysis.

A chemical analysis of the clay by Mr. A. M. Smoot of Ledoux and Co. is as follows:

	Per cent
H_2O at 100°C	.69
H_2O+110°C	11.46
SiO_2	46.44
Al_2O_3	36.36
Fe_2O_3	1.25
TiO_2	0.84
CaO	0.28
MgO	0.18
MnO	0.03
K_2O	1.50
Na_2O	0.42
	99.45

The material selected for analysis was purified by washing and settling, only the slowly settling portion being utilized. It is evident from the analysis that in spite of the care taken in purifying the sample, constituents other than kaolinite remained in suspension. Microscopic examination of the sample as stated above brought out the presence of a small amount of fine mica and feldspar together with traces of other constituents.

Chemical work by Mr. Smoot showed that the sample did not contain more than traces of sulphur trioxide, carbon dioxide and phosphorus pentoxide. It contained some organic matter, presumably humus amounting possibly to two or three tenths of one per cent. All of the iron was reported as ferric oxide, the presence of humus vitiating the determination of iron in the ferrous condition.

In view of x-ray and optical work it seemed advisable to recast the above analysis in an endeavor to approximate the composition of the clay mineral constituent. The K_2O may be attributed to muscovite, the CaO and Na_2O to feldspar. The balance, aside from moisture above 110°C., silica and alumina, may be eliminated as due to various foreign constituents. The recast analysis of the clay mineral constituent compared with kaolinite having the theoretical alumina-silica ration of 1:2 is as follows:

	Recast Analysis	Theoretical Kaolinite
H_2O	13.81%	14.0%
SiO_2	47.80	46.5
Al_2O_3	38.39	39.5
	100.	100.

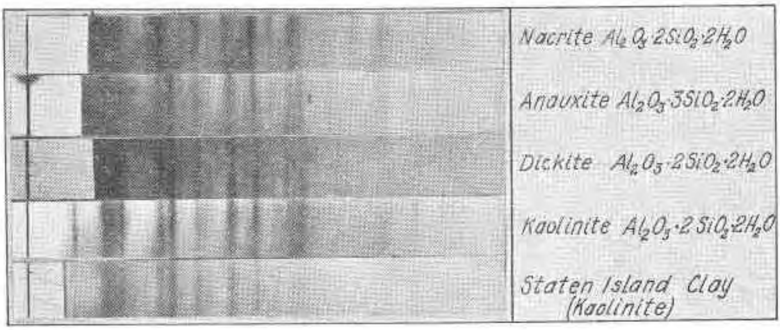

Fig. 2. An x-ray diffraction pattern of the Staten Island clay compared with x-ray diffraction patterns of Nacrite, anauxite, dickite and kaolinite. The Staten Island clay pattern agrees with either kaolinite or anauxite. The chemical composition, however, corresponds with that of kaolinite.

Although the material analyzed was impure, the analysis recast on the basis of eliminating impurities agrees with kaolinite.

X-ray Diffraction Pattern

The x-ray diffraction pattern of the Staten Island clay corresponds to x-ray patterns of kaolinite. Extra reflections, due to the impurities in the clay remaining after washing, do not appear in some patterns or show as one or two lines in others. Such impurities were evidently not present in the washed sample in sufficient quantity to produce lines. Such a situation is not unusual in x-ray diffraction photography. X-ray diffraction measurements of kaolinite are already on record. A detailed description of residual kaolinite from Brooklyn may be used for reference. The x-ray pattern of the Staten Island clay is shown together with x-ray diffraction patterns of kaolinite anauxite, dickite and nacrite in Fig. 2.

The reader is referred to recent descriptions of the kaolin minerals for further comparisons.[5]

Summary

Microscopic examination, *x*-ray study and chemical analysis agree in establishing the identity of the clay mineral constituent as kaolinite. The occurrence of the clay suggests that it was picked from the base of the Raritan formation by passing ice of the Pleistocene glaciation, transported a short distance, and left in the terminal moraine. Although the clay mineral is kaolinite it is intimately mixed with fine feldspar and mica. Such clays have been recognized as "kaolin" for some time but the clay mineral has not previously been correlated with kaolinite according to the modern definition.

[5] *Op. cit.*