CLAY MINERAL COMPOSITION OF CALCAREOUS TILL IN NORTHWESTERN PENNSYLVANIA

JOHN B. DROSTE AND ROBERT W. DOEHLER
University of Illinois, Urbana

INTRODUCTION

The clay mineral content of more than 200 samples of calcareous till in northwestern Pennsylvania has been determined. During the past several years George W. White and his associates have mapped the Pleistocene deposits in northeastern Ohio and northwestern Pennsylvania and collected more than 800 samples of calcareous till. These samples are being studied to determine total size-distribution (White and Shepps, 1952; Shepps, 1953), carbonate content, heavy-mineral content, till fabric (Sitler and Chapman, 1955), clay-mineral composition (Droste, 1956a), and clay-mineral weathering sequences (Droste, 1956b).

Each cross on Figure 1 represents a location where one or more calcareous tills were sampled. The samples were obtained from cut banks of streams, road cuts, recent excavations, and auger or shovel holes. In all instances the samples were taken from Horizon 4 (calcareous, oxidized, brown till) or Horizon 5 (calcareous unoxidized gray till). With the completion of this study, the clay-mineral composition of Pleistocene deposits will be known for an area of more than 6000 square miles in the Allegheny Plateau of northeastern Ohio and northwestern Pennsylvania.

PLEISTOCENE GEOLOGY

Leverett's reports of 1902 and 1934 summarized the earlier work and described his morphological studies. Shepps (1955) studied the glacial deposits along the Pennsylvania-Ohio border, and during the past three summers Professor White and his associates, R. W. Sitler, J. C. Tharin, and the authors have studied in detail the Pleistocene drift of the area shown on Figure 1.

The oldest Pleistocene deposits of this area are distributed as indicated on Figure 1. These deposits are now believed to be Illinoian in age. A few possibly pre-Illinois terrace deposits may exist beyond the Illinoian, but no pre-Illinoian till has been found beyond the Illinoian boundary.

The oldest till of Wisconsin age in the area underlies younger Wisconsin drift except in a few places (White and Shepps, 1952: 1388). It is similar to till called Tazewell (White, 1953: 39, pl. 26) at the surface in the Akron, Ohio, region and underlying younger till elsewhere in northeastern Ohio.

Younger Wisconsin tills have been traced from northeastern Ohio where they have been assigned a Cary age (White, *op. cit.*). Four post-Tazewell till sheets have been differentiated: 1) till extending from the Wisconsin boundary almost to the De-

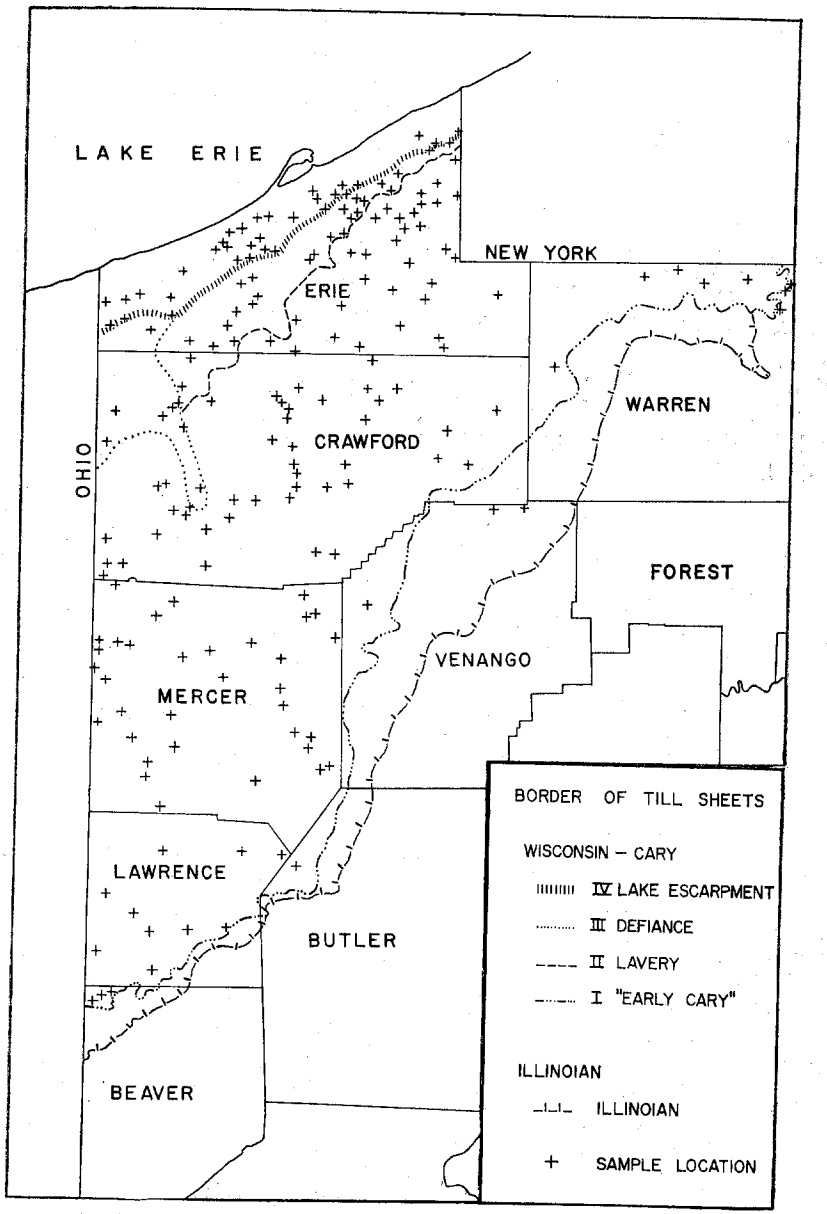

FIG. 1.—Drift sheets of northwestern Pennsylvania and sampled locations. Boundaries from work of White, Droste, Shepps, and Sitler.

fiance moraine (called "Early Cary" in Ohio); 2) narrow band of till just south of the Defiance Moraine and closely related to it (recognized only recently in Ohio, "Lavery" of Shepps, 1955); 3) sheet of clayey till from the Defiance moraine to the Lake Escarpment moraine system ("Late Cary" of White, 1953); and 4) the Lake Escarpment moraines.

Outcrops in which multiple tills are exposed are not common throughout northwestern Pennsylvania, but enough sections have been found to establish the Cary substages just described.

Laboratory Procedure

Oriented aggregates of the fine grain-sizes of each sample were made on glass slides (Grim, 1934), and diffraction patterns were obtained on a XRD-3 General Electric recording defractometer using filtered copper radiation. In addition to the air-dried samples, spectrometer traces were made on slides treated with ethylene glycol, NH_4Cl, and heated to 450° C.

Initially, the less-than-one micron fraction was separated from 40 samples by sedimentation in water without the use of dispersing agents and without acid leaching to remove carbonates. The less-than-eight micron fraction from another part of these same samples was obtained in the same way, and the spectrometer traces of the two size-fractions were compared. Except for the great increase of quartz and calcite lines very little difference could be seen between these size-fractions. Since the less-than-eight micron fraction requires less time to obtain, it was used to determine the clay-mineral composition of the remaining 160 samples. This procedure is the same as the one used in the study of the clay-mineral composition of tills in northeastern Ohio (Droste, 1956a).

Discussions and Conclusions

In all samples a peak due to chlorite occurs between 14.2Å and 14.6Å. The intensity and sharpness of this peak is quite variable and changes shape and position after glycol treatment, NH_4Cl treatment, and heat treatment. The more intense and sharp the peak is in the air-dried, untreated sample, the less it is modified after glycolation, NH^+_4 saturation, and heat treatment. The 14Å peak remains essentially unchanged in gray calcareous samples (Horizon 5), indicating the presence of well-crystallized chlorite.

In the brown calcareous samples (Horizon 4) the nature and modifications of the X-ray patterns after treatment with ethylene glycol, NH_4Cl, and heat depend upon where the sample is taken within Horizon 4. The nearer the sample is taken to Horizon 5, the less the peak characteristics change after the various treatments.

In the lower Horizon 4 samples the 14Å peak in the air-dried slide is as intense as but broader than in the Horizon 5 sample. The peak in these samples is partially lost after heating and remains essentially unchanged after glycolation and NH_4Cl treatment. The 14Å peak from a middle Horizon 4 sample is less intense and broader than in the lower Horizon 4 sample. The peak shifts to 15Å after glycolation, to 13.2Å after NH_4Cl treatment, and is completely lost after heating to 450°C.

The 14Å peak of a sample of upper Horizon 4 is broader and less intense than in the sample taken from the middle of Horizon 4. This peak may shift as high as 15.8Å after glycolation and as low as 12.6Å after NH_4Cl treatment. The nature of the 14Å peak (and appropriate higher orders) in Horizon 4 samples indicates that the well-crystallized chlorite of Horizon 5 is gradually hydrated. The hydration occurs by protons joining hydroxyls in the brucite sheets of the chlorite, and this leads to a mixed, layered, vermiculite—chlorite clay mineral. The hydration of every brucite sheet does not start at the same time—nor does every layer hydrate at the same rate—so that "islands" of magnesium ion surrounded by H_2O "grow" at random in the brucite sheet. It is important to point out that clay-mineral alteration begins in the lower part of Horizon 4.

A sharp, intense 10Å peak with appropriate higher orders is present in all samples, indicating the presence of illite. In the gray calcareous samples of Horizon 5 and in the samples taken in the lower part of brown calcareous Horizon 4 the 10Å peak in the air-dried samples is asymmetrical on the low-angle side (high d-spacing side) of the peak. The loss of this asymmetry after ethylene glycol and heat treatment indicates that some of the illite is hydrated. This hydration has probably occurred because of the removal of some of the potassium ion and entrance of water between the mica sheets. The removal of potassium ion from between the mica sheets is completely random, and in the samples taken from the upper part of Horizon 4 a mixed layering of illite-montmorillonite is very evident.

A 7Å peak is found in all samples. In almost all cases the characteristic of the 7Å peak can be explained as the (002) order of the 14Å - chlorite peak. In a few samples the entire diffraction diagram gave slight hints of the presence of kaolinite, but this is to be expected because of the tremendous variety possible in chlorites. Until a fool-proof method is devised to identify kaolinite in the presence of chlorite, small amounts of kaolinite will be missed when it is mixed with large amounts of chlorite. Kaolinite could not be definitely identified in the samples taken in Pennsylvania. Evidence is present that kaolinite occurs in the samples of tills of the same age in northeastern Ohio (Droste, 1956a), but as the Ohio-Pennsylvania state line is approached the kaolinite content of the tills in Ohio decreases. This disappearance of kaolinite in Pennsylvania may be a reflection of the clay-mineral variation in the composition of the local bedrock.

The approximate mean abundance of illite and chlorite in the samples studied is 60% and 40%, respectively. The amount of illite varies between 50 and 70% and the amount of chlorite varies between 50 and 30%. The quantitative estimation of the clay-mineral composition was made by the method described by Johns, Grim, and Bradley (1954).

Several complete weathering profiles of Wisconsin age were sampled to study the clay-mineral alteration throughout this entire profile. The data obtained from this study will not be presented here, but the alteration of the clay minerals does follow

the same general scheme already described for tills of the same age in Ohio (Droste, 1956b).

All these studies show again that, to understand completely the alteration of clay mineral by weathering in calcareous till, a sample of Horizon 5 must be included.

Summary

The clay-mineral composition of all fresh (Horizon 5) unoxidized, unleached tills of Illinoian and the five different episodes of Tazewell and Cary time is illite and chlorite. Unlike some of the tills of the same age in Ohio, none contain kaolinite in sufficient amounts for positive identification.

The clay-mineral composition of the calcareous, oxidized (Horizon 4) tills is variable and entirely dependent on the amount of alteration by weathering of the illite and chlorite present in Horizon 5.

Literature Cited

Droste, J. B. 1956a. Clay minerals in calcareous till in northeastern Ohio. Jour. Geol., 64: 187-190.

1956b. Alteration of clay minerals by weathering in Wisconsin tills. Geol. Soc. Amer. Bull. 67: 911-918.

Grim, R. E. 1934. The petrographic study of clay minerals—a laboratory note. Jour. Sed. Petrol., 4: 45-46.

Johns, W. D., R. E. Grim, and W. F. Bradley. 1954. Quantitative estimation of clay minerals by diffraction methods. Jour. Sed. Petrol., 24: 242-251.

Leverett, F. 1902. Glacial formations and drainage features of the Erie and Ohio basins. U.S. Geol. Surv. Monog. 41: 1-802.

1934. Glacial deposits outside the Wisconsin terminal moraine in Pennsylvania. Bull. G-7, Penn. Geol. Surv., 4th Ser., 123 pp.

Shepps, V. C. 1953. Correlation of the tills of northeastern Ohio by size analysis. Jour. Sed. Petrol., 23: 34-45.

1955. The glacial geology of a part of northwestern Pennsylvania. Unpubl. doctoral thesis, Univ. Ill., Urbana.

Sitler, R. W., and C. A. Chapman. 1955. Microfabrics of till from Ohio and Pennsylvania. Jour. Sed. Petrol., 25: 262-269.

White, G. W. 1953. Geology and water-bearing characteristics of the unconsolidated deposit of Cuyahoga County. *In* Winslow, J. D., White, G. W., and Webber, E. E., The water resources of Cuyahoga County, Ohio. Ohio Div. Water Bull. 26: 36-41.

White, G. W., and V. C. Shepps. 1952. Characteristics of Wisconsin tills in northeastern Ohio (abstr.). Geol. Soc. Amer. Bull. 63: 1388.