

CLAY MINERALS IN LAKE ERIE SEDIMENTS

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ABSTRACT

A clay-mineral and petrographic study has been made of 14 different samples of sediments from the bottom of Lake Erie. Thermal analyses, optical studies, and *x*-ray diffraction patterns have been used to determine the nature of the clay-mineral composition of these sediments. The data indicate that the predominant clay-mineral is of an illite character.

The analyses of these samples show a good correlation between the depth of water under which the samples were secured, their location with regard to shore line, and the amount and character of residue (particles greater than two microns in diameter) and clay (particles smaller than two microns in diameter).

INTRODUCTION

Clay-mineral studies and petrographic studies of sediments have been made of numerous different types of materials in the last few years (1). The clay-mineral composition has been determined of shales, clays, soils, limestones, dolomites, and of ocean sediments utilizing techniques which have become popular for this type of work. They are thermal analysis, optical studies, *x*-ray analysis, and chemical analysis. It was thought advisable to apply some of the same techniques to fresh water lake sediments in order to determine their character.

The present paper deals with a study of samples obtained during a cooperative survey made of Lake Erie in 1928 and 1929 by the United States Bureau of Fisheries, the New York State Conservation Department, the Ontario Department of Game and Fisheries, the Health Department of the City of Buffalo, and the Buffalo Society of Natural Sciences (2, 3). Thermal analyses, optical studies, and *x*-ray analyses were made of these samples with the particular object of determining their clay-mineral composition.

The samples studied are as representative of the many variations offered that it was possible to obtain. Some are from locations in the deepest part of Lake Erie; some from comparative shallows; and some are from locations where the bottoms are known to be composed of sand, limestone, or mud.

The locations from which the various samples were collected are shown in Fig. 1. The sample numbers and the depth of the water at the location from which the samples were taken are given in Table 1 in order of increasing depth.

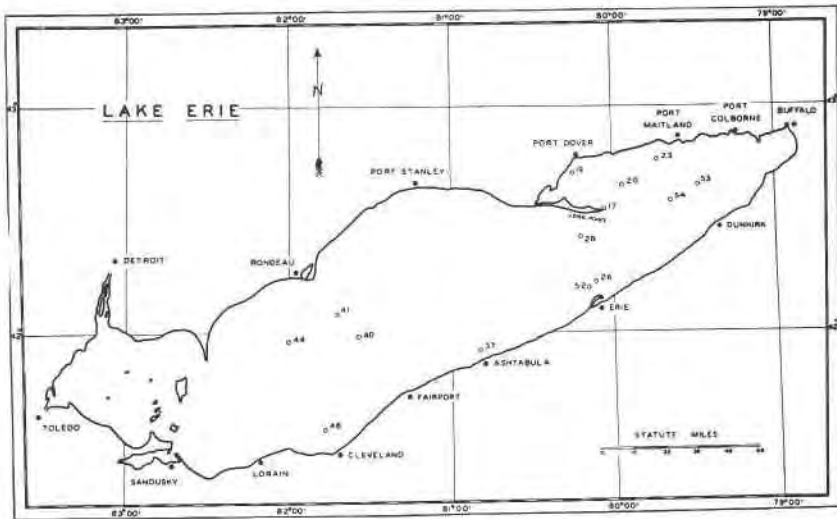


FIG. 1. Map of Lake Erie showing the number and location from which the samples were collected.

TABLE 1

| Sample Number | Depth in Meters | Per Cent Loss of CO ₂ and O.M.* | Per Cent Clay | Per Cent Residue |
|---------------|-----------------|--|---------------|------------------|
| 19 | 9.0 | 22.4 | 9.0 | 68.6 |
| 52 | 13.5 | 22.8 | 10.1 | 67.1 |
| 37 | 17.0 | 9.2 | 25.4 | 65.4 |
| 46 | 18.0 | 11.0 | 35.2 | 53.8 |
| 26 | 21.0 | 9.1 | 11.5 | 79.4 |
| 23 | 21.0 | 17.9 | 15.8 | 66.3 |
| 44 | 23.0 | 9.3 | 52.0 | 38.7 |
| 17 | 24.0 | 16.5 | 4.3 | 79.2 |
| 41 | 24.0 | 6.7 | 44.1 | 49.2 |
| 40 | 24.0 | 5.5 | 64.5 | 30.0 |
| 53 | 29.0 | 12.2 | 19.5 | 68.3 |
| 28 | 35.0 | 16.9 | 32.2 | 50.9 |
| 20 | 37.0 | 11.5 | 39.6 | 48.9 |
| 54 | 52.0 | 11.7 | 35.9 | 52.4 |

* Organic matter.

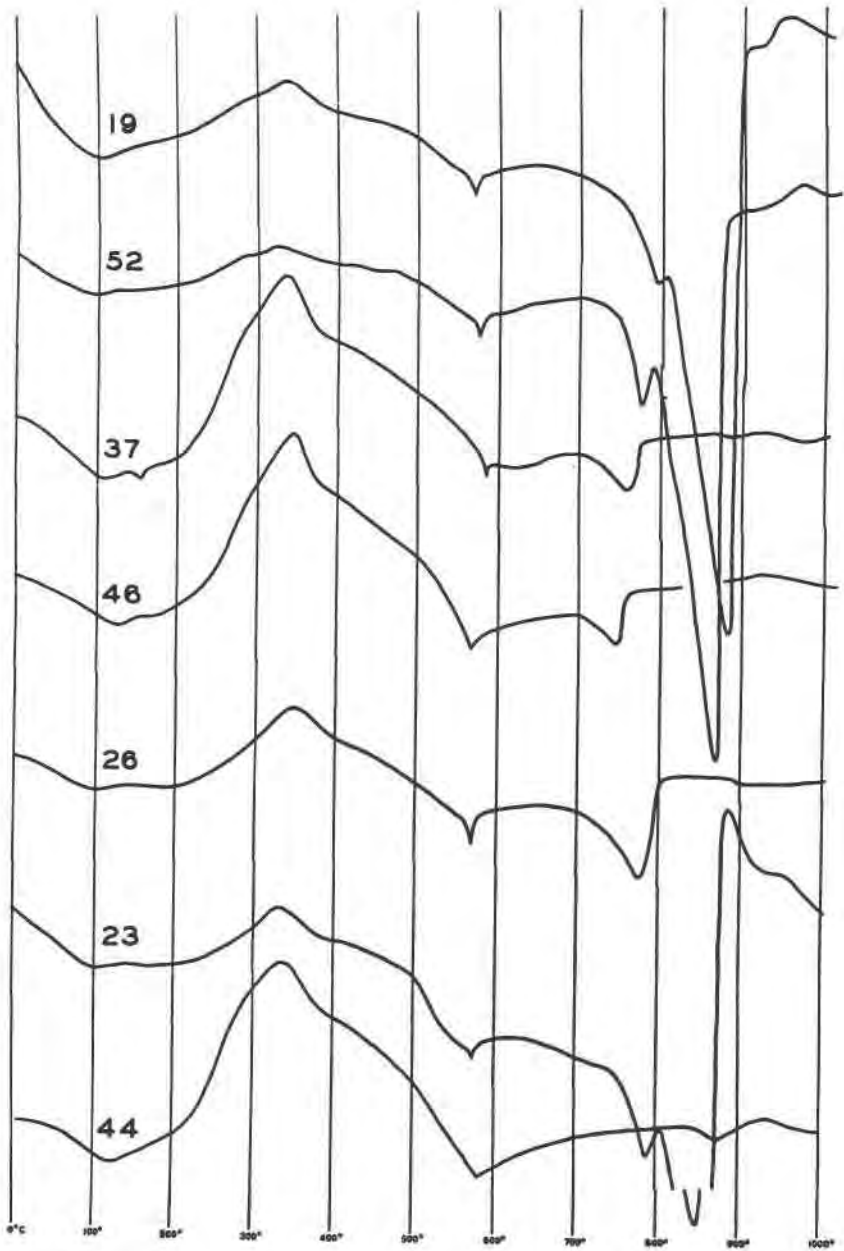


FIG. 2. Differential thermal analyses of untreated samples.

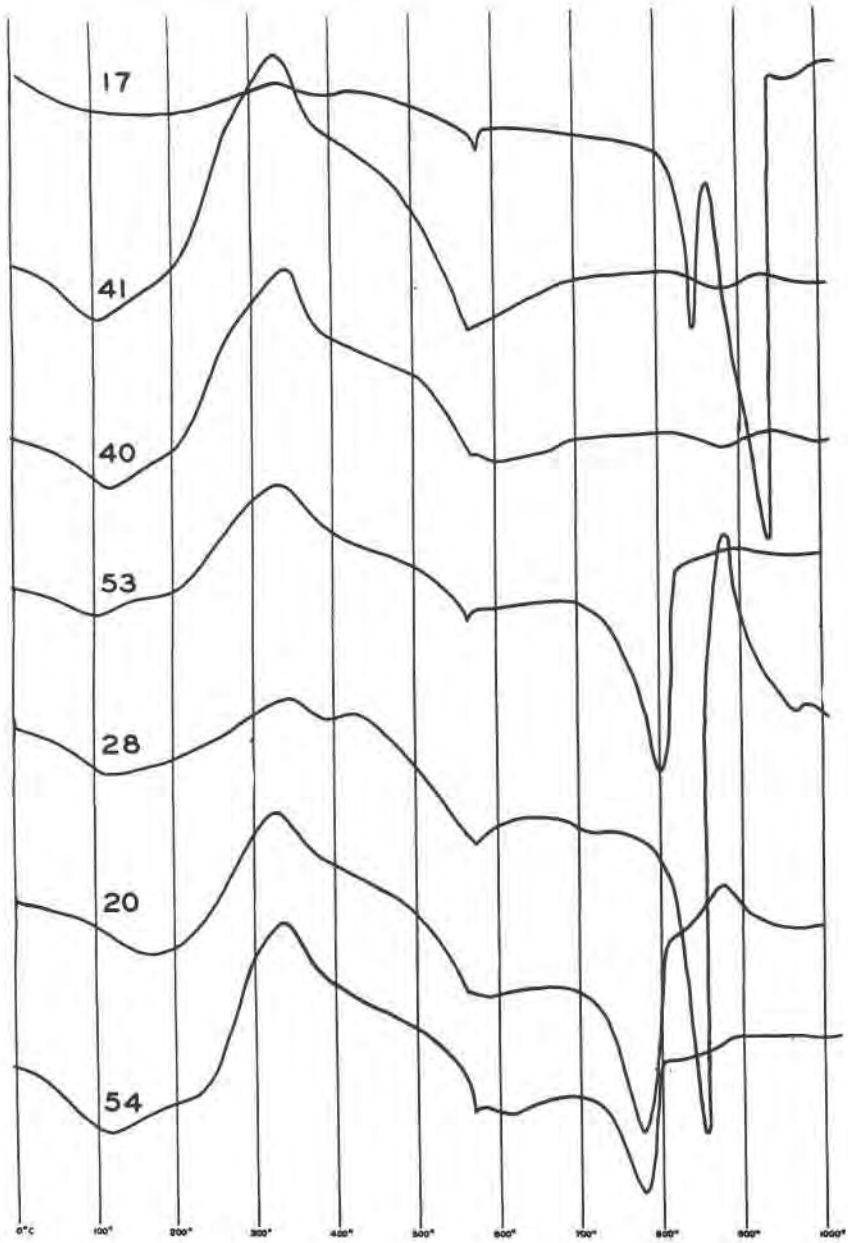


FIG. 2 (continued). Differential thermal analyses of untreated samples.

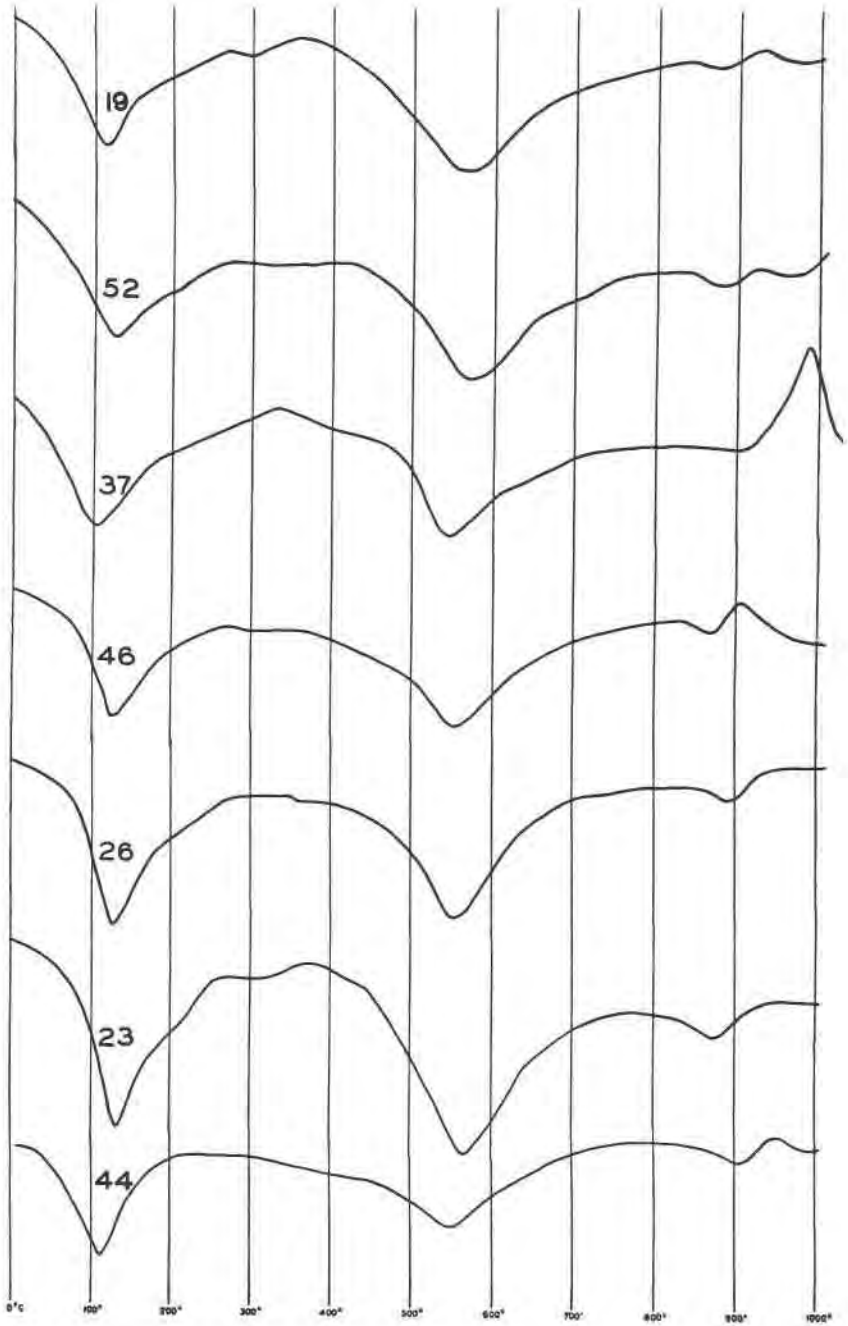


FIG. 3. Differential thermal analyses of clay fractions.

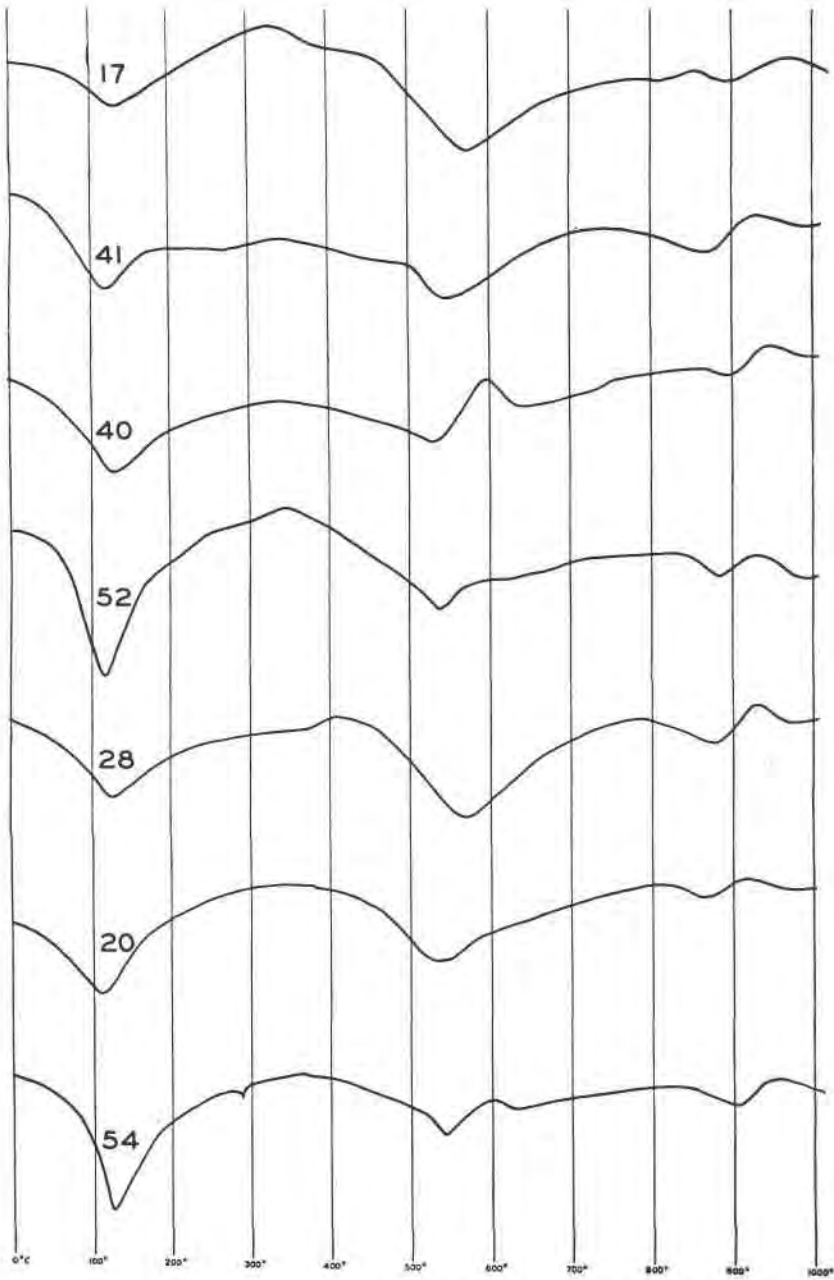


FIG. 3 (continued). Differential thermal analyses of clay fractions.

EXPERIMENTAL PROCEDURE

Differential thermal analyses were made of samples representative of the materials as collected in order to obtain information on the composition of the whole samples. The apparatus used is like that commonly used in this work and has been described before (4). Figure 2 shows the thermal diagrams of the whole samples in their original condition.

The samples were then treated with dilute hydrochloric acid and hydrogen peroxide in order to destroy the carbonates and organic matter. The organic matter was destroyed following the method of Bray (5). This was necessary to obtain a fractionation of the samples and to allow concentration of the clay-minerals for further and more complete identification. Also by destroying the carbonates and organic matter the thermal reactions of the remaining materials are less apt to be obscured by the more vigorous reactions of the carbonates and organic material. The percentages of carbonates and organic matter removed by this treatment are given in Table 1.

The treated samples were then put into suspension by the addition of ammonium hydroxide and a fractionation was made at two microns effective particle size by siphoning that part of the suspension containing only particles two microns or less in diameter. A fractionation of this type concentrates the clay-minerals in one fraction, the colloid, and the non-clay-minerals in another fraction, the residue. This facilitates identification of the clay-minerals by all types of analyses. The fractionation was repeated until the separation was considered complete. Table 1 shows the per cent of clay-mineral (consisting of particles smaller than two microns in diameter) and the per cent of residue (consisting of particles greater than two microns in diameter).

Differential thermal analyses were then made of each of the clay fractions of the samples. Diagrams representing these analyses are given in Fig. 3.

Both the residue and clay fractions of all the samples were studied microscopically and *x*-ray diffraction patterns were secured of several of the clay fractions.

EXPERIMENTAL RESULTS

Untreated samples

Differential thermal analyses of the untreated, whole samples practically all show slight endothermic reactions at about 125°C. This initial reaction is due to the primary dehydration of adsorbed water. For some of the samples, Nos. 37, 46, 44, 41, 40, 53, 20, 54, this reaction is followed by an exothermic reaction between 200°C. to 500°C., which is the burning

off of the organic matter. All of the curves have the typical quartz endothermic reaction at about 560°C. The sharpness and magnitude of this reaction is semi-quantitative and can be correlated to a degree with the fractionation data given in Table 1. The endothermic reaction between about 750°C. and 950°C. is believed to be caused by the presence of carbonates, probably both calcium and magnesium carbonates, and combinations of both, such as dolomite.* No indication of the amount and type of clay is indicated in any of these diagrams with the possible exception of Nos. 44, 41, and 40.

Microscopic study of the whole samples revealed the coarse, non-clay, inorganic part of all the samples contained quartz, sand, shell fragments, limestone, dolomite, and rock fragments. Many of the samples had to be carefully washed in distilled water in order to permit determinations of the constituents.

Treated clay fractions

By destroying the carbonates and organic matter as described in the procedure, and by separating the clay or minus two micron material, thermal analyses are made of value for determining the type of clay. Figure 3 shows the differential thermal analyses of the clay fraction of these samples. In contrast to the diagrams for the whole samples, the initial dehydration reaction is much sharper and entirely completed at about 125°C. which is common in clays. This reaction is followed by another endothermic reaction at about 550°C. and by double endothermic, exothermic reaction between 850°C. and 1000°C. These reactions are believed to be indicative of an illite type of clay-mineral.

The striking similarity of all the curves is noteworthy. For all samples the effectiveness of the removal of the carbonates, organic matter, and quartz is clearly shown.

Microscopic study revealed that the clay fractions (minus two microns, effective diameter) were too coarse to allow accurate determination of optical properties. Practically all of the material had a mean index refraction of about 1.56. Some of the samples were redispersed and a small amount of the very finest material collected. The optical properties of this material were: $\gamma = 1.582$ to 1.606, $\gamma - \alpha = .032$ to .036 (-) and it appeared to be quite pure.

X-ray diffraction analyses were secured of four of the clay samples chosen to be representative of the entire group; Nos. 52, 26, 17, 28. With the exception of the diffraction lines of quartz, few well defined diffraction

* Unpublished work by R. A. Rowland and F. L. Cuthbert.

lines were obtained. The patterns strongly suggest that the bulk of the material represents a random growth of mixed layers with frequent indications of small amounts of material of a glauconitic and montmorillonitic type.

DISCUSSION AND SUMMARY

The application of modern techniques of clay analysis are shown to be of great aid in studying fresh water lake sediments. Differential thermal analyses are of value, particularly when coupled with optical and *x*-ray studies, not only in determining the nature of the clays but also to obtain an approximation of the general composition of the entire sample.

Relation of the composition of the samples to location

The analyses of the whole samples show a good correlation between depth of sample, location of sample with regard to shore line, amount of clay material. The samples, as collected, or in the raw state, are composed largely of quartz, carbonates, organic matter, and clay of varying percentages. Those samples, collected from shallow areas of the lake, Nos. 19, 52, 37, contain large amounts of non-clay material as shown by both thermal analyses and by the fractionation data. Also, samples from locations near the shore line, Nos. 17, 26, 23, are shown to contain little clay, more or less independent of the depth. Samples from the deeps or from areas near the middle of the lake contain the largest amounts of clay and smallest amounts of quartz and carbonates, Nos. 40, 44, 41, and 54. Sample No. 20, while from a comparatively deep part of the lake, 37 meters, is also quite close to shore. The location is in Long Point Bay which is known to have a muddy bottom. Consequently, the sample contains a relatively high per cent of clay.

Type of clay-mineral present

The clay fraction of the samples is believed to be composed largely of an illite-type of material that is commonly present in soil materials, shales, etc. This conclusion is supported by the thermal curves, characterized by the relatively small initial dehydration peak, the endothermic reaction at about 550°C. and the smaller, double endothermic, exothermic reaction between 850°C. and 1000°C. The optical data for the purer clay is within the range of values reported for other illite clays.

X-ray diffraction patterns, secured on four samples, indicate that much of the material is not well crystallized but rather follows a pattern of random growth, perhaps an intimate mixture of layers of different clay-

minerals. This intermingling of layers of different clay-minerals has been reported before and is thought to occur more or less commonly, particularly in complex systems like soils.

While the x -ray data do not appear, at first glance, to substantiate the conclusions derived from the differential thermal analyses and the optical studies, such discrepancies are not at all unusual when working with materials of this nature. Due to the poor degree of crystallization it is difficult to interpret the diffraction patterns obtained in terms of well-defined clay-minerals. The data indicate the necessity of using as many methods of analyses as possible when attempting to make clay-mineral determinations of materials of this nature.

Source of sediments

The source of these Lake Erie sediments, in view of this work, affords an interesting problem for speculation. The rocks of the Lake Erie basin are Devonian in age and composed almost entirely of shales; the Chemung, Portage, Genesee, Hamilton, and Marcellus formations. The Onondaga formation, a massive limestone, is the only formation of any significance that is not shaly, and outcrops almost entirely on the northern side of the lake. While no clay-mineral analyses are known to be available of these shales, it can be supposed that they would be illite in nature. Also, the glacial till, which practically covers the drainage area of Lake Erie, may well be the source of the clay sediments.

The presence of carbonates in the samples, aside from the shell fragments noted, can also be expected when we consider the large areas of exposed limestone and dolomitic rocks in the immediate vicinity of Lake Erie.

More detailed investigations of the clay-mineral nature of fresh water lake sediments should present interesting results leading to a better understanding of the genesis of clay-minerals. Similar studies should also aid in understanding the history of many of our commercial clay deposits as many are located in the basins of extinct lakes.

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