AMERICAN MUSEUM NOVITATES

Number 209 | Published by THE AMERICAN MUSEUM OF NATURAL HISTORY New York City | Feb. 17, 1926

55.1,3(74.9)

THE VARVED CLAYS AT LITTLE FERRY, NEW JERSEY

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INTRODUCTION

The presence of a series of deposits which afford a precise record of seasonal deposition in any one of the five better-known eras of geologic time is of special interest. Such deposits do exist, but their time element is for the most part an unknown quantity. Where found they consist generally of lake deposits which have resulted from deposition under one or the other of the two extremes of climate, namely: (1) either a waning glacial period or (2) an intensive arid condition accompanied by the deposition of layers of salt and red beds.[1]

This paper deals with stratified beds which have the varve, the amount of aqueo-glacial sediment deposited in one year, as the unit of deposition and time measurement. Deposits of this character, which were for the most part laid down in lakes as the ice of the last glaciation retreated northward, are not uncommon surface or near surface deposits in glaciated territory in the United States, Canada, Sweden, Finland, Bechuanaland, Cape Colony and Australia, but comparatively few of them have been studied from the standpoint of the number of varves or years involved, except in Sweden and Finland.

In Sweden, De Geer[2] and his students have interpreted the significance of these annual deposits, developed a method for their correlation in localities within the same climatic zone and determined a period of 13,500 years for the retreat of the ice of the last glaciation from central

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[1]Reeds, Chester A., 1923, 'Seasonal Records of Geologic Time,' Natural History, New York, XXIII, pp. 370–380.

[2]De Geer, Gerard, 1882, 'Om en postglacial sänkning i södra och mällersta Sverige,' Geol. Fören. Förhandl., VI, pp. 149–162, reference on p. 159 (Stockholm); 1884, 'Om möjligheten af att införa en kronologi för istiden,' Geol. Fören. Förhandl., VII, p. 3 (Stockholm); 1885, 'Om istidens kronologi,' Geol. Fören. Förhandl., VII, 512–513 (Stockholm); 1912, 'A geochronology of the last 12,000 years,' Compte Rendu Congrès Géol. Internatl. à Stockholm,' 1910, pp. 241–253 (Stockholm); 1912, 'Geochronologie der letzten 12,000 Jahre,' Geol. Rundschau, III, pp. 457–471 (Leipzig); 1914, 'Om naturhistoriska kartor över den baltiska dalen,' Pop-Naturvet. Revy, pp. 189–200 (Stockholm); 1921, 'Correlation of late glacial clay varves in North America with the Swedish time scale,' Geol. Fören. Förhandl., XLIII, pp. 70–73 (Stockholm); 'Nordamerikas kvartärgeologi belyst av den svenska tidskalan,' Geol. Fören. Förhandl., XLIII, pp. 497–499 (Stockholm); Antevs, Ernst, 1915, 'Landisens recession i nordöstra Skåne,' Geol. Fören. Förhandl., XXXVII, pp. 353–366 (Stockholm); 1921, 'Senkvartära Nivaförandringar i Norden,' Avtryck ur Geologiska Föreningens, I (Stockholm, Nov.–Dec.); 1922, 'On the late-glacial and post-glacial history of the Baltic,' Geogr. Review, XII, No. 4, October. Lidén, Ragnar, 1911, 'Om isafsmältningen och den postglacial landhöjningen i Angermanland,' Geol. Fören. Förhandl., XXXIII, pp. 271–280 (Stockholm); 1913, 'Geokronologiska studier öfver det finiglaciala skedet i Angermanland,' Sveriges Geol. Undersökning, Ser. Ca, No. 9 (Stockholm).

Scania, the southernmost part of Sweden, to the present small ice caps in north central Sweden.[1]

In Finland, Sauramo[2] has also worked out a similar record of retreat of the ice of the last glaciation.

In the United States, Antevs,[3] a Swedish geologist, in 1921–1922 determined 4,400 years in the Connecticut River valley as the retreat of the ice of the last glaciation from Hartford, Connecticut, to St. Johnsbury, Vermont, a distance of 185 miles. In 1923, Antevs studied the varved clay deposits in eastern Canada and determined an additional record of some 7,000 years with notable gaps, due either to the absence of the clay in certain areas or to its disturbed or concealed character in other districts.[4]

In 1919, Sayles[5] of Harvard University compared types of banded clay of Pleistocene and Permian ages in New England and presented a historical résumé of varve clay studies in the United States, Canada and Sweden.

In December, 1923, a short account of the studies by the writer on the Postglacial clay at Little Ferry, N. J., was delivered before the Washington meeting of the Geological Society of America. An additional record of 2,550 consecutive years was noted.[6]

The 11,400 years determined by Antevs in the Connecticut valley and Canada, together with the 2,550 varves for the Little Ferry district, give a total known record of 13,950 years for American localities, a period 450 years longer than the Swedish record, determined by De Geer and his assistants.

No doubt as these geochronological studies progress, many additional years will be added to the present known record of the time that has elapsed since the ice of the last glaciation retreated northward from Staten Island, the southernmost point reached by the Wisconsin glaciation in eastern North America. An estimate of 25,000 to 50,000 years as the length of Postglacial time has been made by recent writers,[7] but this

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[1]Osborn, H. F., and Reeds, C. A., 1922, 'Old and New Standards of Pleistocene Division in Relation to the Prehistory of Man in Europe,' Bull. Geol. Soc. Am., XXXIII, pp. 411–490.

[2]Sauramo, Matti, 1918, 'Geochronologische Studien über die spätglaziale Zeit in Südfinnland,' Bull. Comm. Géol. de Finlande, No. 50; 1918, also Finnia, XLI, No. 1, pp. 1–44 (Helsingfors); 1923, 'Studies on the Quaternary Varve Sediments in Southern Finland,' Bull. de la Com. Géol. de Finlande, No. 60 (Helsingfors).

[3]Antevs, Ernst, 1922, 'The Recession of the Last Ice Sheet in New England,' American Geographical Society, Research Series, No. 11, New York.

[4]Antevs, Ernst, 1925, 'Retreat of the Last Ice-Sheet in Eastern Canada,' Geol. Surv. of Canada, Memoir 146, pp. 1–142, 9 pl., 37 figs.

[5]Sayles, R. W., 1919, 'Seasonal deposition in aqueoglacial sediments,' Memoirs Museum of Comp. Zool., XLVII, No. 1, Cambridge, Mass.

[6]Reeds, C. A., 1924, 'Post-glacial clays at Little Ferry, N. J.,' Bull. Geol. Soc. Am., XXXV, p. 66.

[7]Coleman, A. P., 1914, 'An estimate of postglacial and interglacial time in North America,' Int. Geol. Congress, XII (Toronto, 1913), Compte Rendu, 435–449. Osborn, H. F., 1915, 'Men of the Old Stone Age,' pp. 41, 510.

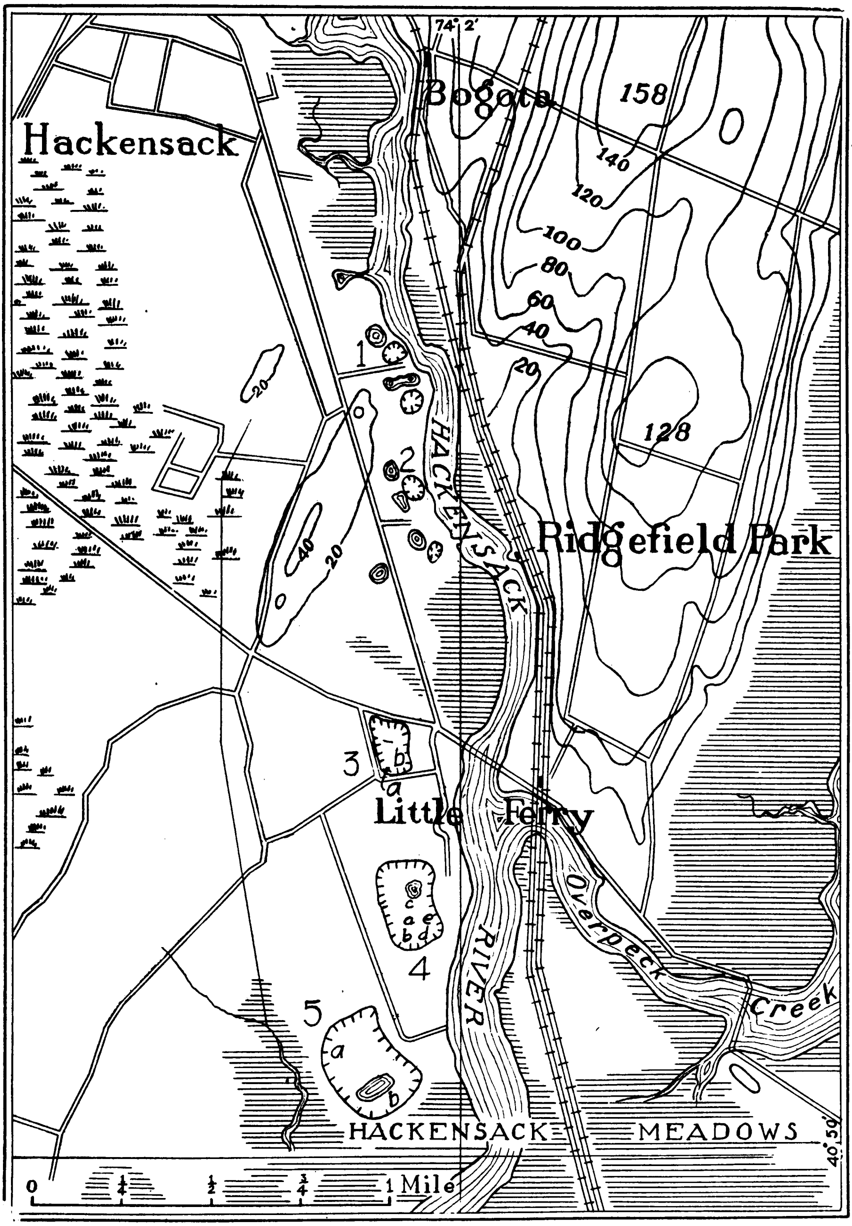

Fig. 1. Sketch map of the Little Ferry district, New Jersey, showing the position of clay pits 1 to 5.

may have to be modified when the precise determination afforded by the study of varve deposits has been concluded.

THE LITTLE FERRY DISTRICT

The clay pits about Little Ferry afford a key section for the varve clays in the middle portion of the Hackensack valley. During a portion of the summers of 1923 and 1924, the author, with Mr. P. B. Hill as field assistant and Mr. E. J. Foyles as laboratory assistant, investigated the clays of the region under the auspices of The American Museum of Natural History. Our attention in the field was centered on the five clay pits, numbered 1 to 5, Fig. 1, which are confined to a two-mile strip along the west bank of the Hackensack River from Pit 1, a mile above Little Ferry, to Pit 5, a mile below that village, that is, from the town of Hackensack south to the upper end of the Hackensack Meadows. The National Bank of Little Ferry, which is near the center of the village, has the location Long. 74° 2′ W., Lat. 40° 51′ N. This locality is about fourteen and one half degrees farther south than De Geer's southernmost locality in Sweden and about one degree south of the parallel of Hartford, Connecticut, the southernmost of Antevs' localities in the Connecticut River valley.

Seasonal Deposition.—The varve or laminated clays, in the five pits mentioned above, represent stratified sediments which were laid down seasonally in a fresh-water lake year after year as the ice of the Wisconsin stage gradually retreated northward up the Hackensack valley. Each varve consists of two members: (1) a light-colored gray, yellowish or brownish "summer" layer which is composed generally of very fine sand, locally called "quicksand," and an intermingling of coarse clay particles; and (2) a dark bluish or red "winter" layer consisting of very fine clay particles. Occasionally the "summer" layer contains one or more bands of impure clay intercalated between laminæ of very fine sand. These intraseasonal bands are interpreted as representing relatively short periodic incursions and settlements of sediment brought in by the subglacial and englacial rivers during variable periods of melting in the warmer months of the year. Generally speaking, the sandy "summer" layer represents the influx into the lake of the coarser sand and clay particles during the summer melting or ablation period of the ice, while the pure or fat clay denotes the settlement during the long winter months of the fine clay particles which remained in suspension following the turbulent summer incursions.

The "summer" layer is generally thicker than the "winter" band, but frequently they are of the same thickness. In the Little Ferry district the varves vary in thickness at different levels from one inch to one sixteenth of an inch with a general average of about three sixteenths of an inch. Contiguous varves may be variable as to width, but as a rule they run in series with the varves either uniform as to thickness or gradually increasing or decreasing in thickness, usually the latter. At the nodes between the series, marked changes in the relative thickness of the varves appear. Near the Hackensack River and the base of the section, the varves are prevailingly thicker than elsewhere.

OVERLAPPING OF THE VARVES.—The varves comprising the Little Ferry deposits are not evenly stacked as the cards in a deck, but are feathered out similar to the shingles on the roof of a house when laid with the thicker end up as noted in Fig. 2. Throughout the greater portion of their extent, however, the varves are in contact.

The northward extension of a designated varve, beyond that of its predecessor, represents the amount of ice retreat for that year. Furthermore, its northern limit indicates the position of the ice front at the close of the melting season for that particular year. Thus by noting the northern limits of successive varves the various annual retreat stages of the ice may be accurately determined.

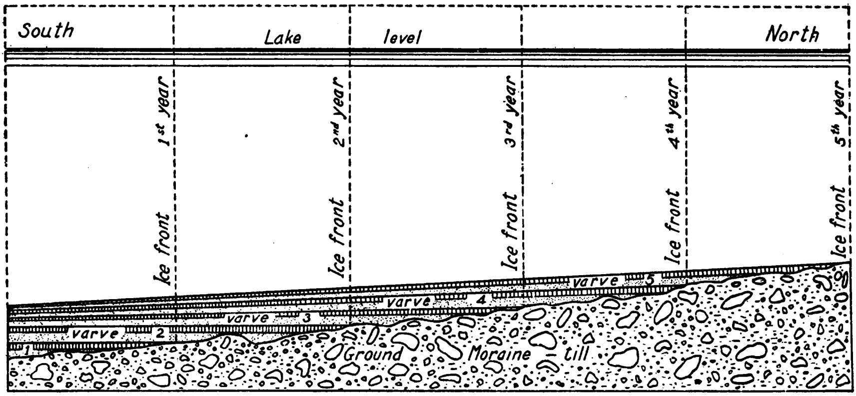

Fig. 2. Diagram showing the manner of deposition of varve clay layers in fresh-water lakes off a receding ice front for five successive years.
Vertical shading, winter layers; dotted areas, summer layers.

It will also be detected that a limited portion of each varve, that is, the amount of its northward extension over its predecessor, will rest directly upon the virgin strip of territory set free by the ice during the summer retreat. Laterally the varve will extend to the limits of the basin existing at the level of the varve. The basal varves occupy the lowest levels and narrower channels in the bottom of the basin while the higher ones have a wider extent due to the outward and upward trend of the bottom of the basin.

THE UNDERLYING PAVEMENT.—In the Hackensack valley the proximal portion of every varve rests upon the underlying pavement of red glacial till composed of a heterogeneous mixture of sand, gravel, boulders and clay, which the advancing glacier derived from the underlying "red beds" of Triassic age; in retreat this same glacier left the till spread out promiscuously over the uneven surface of the land. In Pits 1 and 3, the clay has been entirely removed from several acres of ground and the former bottom of glacial Lake Hackensack is revealed as a prevailingly even surface composed of till and studded with gravelly hummocks and occasional esker-like ridges of limited extent, Fig. 3.

MAJOR FIELD CORRELATIONS.—The problem is primarily a stratigraphic one. Fossils do not occur, hence the methods of the stratigraphic palæontologist are not serviceable. By using the physical characters of the varves, however, a closer correlation was made than could have been secured had fossils been present. A few varves and certain groups of varves have such pronounced characters that they are immediately recognized wherever observed throughout the district. For instance, in Pits

Fig. 3. Photograph of Pit 3 looking southeast from position (a) of Fig 1.

The underlying pavement consisting of red till appears in the foreground; on the right a gravelly hummock, and in the background the overlying deposits of varve clay and "Yellow Loam."

4 and 5, which are a half mile apart, a distinctive red band with an equally striking series of four gray calcareous bands some 18″ above, were noted in both pits. These prominent stratigraphic features, together with three distinct zones of thick red varves, near the base of the section, furnished striking data for the major correlation of the sediments. Except for the initial basal varves which were found disturbed and illegible in two places, and those which have been partially removed by erosion over a considerable area at the top, it was observed that every varve extended through the five pits and intervening territory of the Little Ferry district.

DATUM PLANE.—In Pits 3, 4 and 5, a series of very thin varves, followed abruptly by a series of coarse ones, was noticed. The plane separating these two strikingly different series of varves was used as the datum plane or zero line. As yet no connection has been established between this datum plane and our present chronology. The varves below this plane were designated by a negative sign, those above by a positive one.

METHODS USED IN COLLECTING SAMPLES.—Actual sections of the clay were taken in copper trays two feet long by two inches wide by one inch deep, by inserting each tray into a closely fitting steel form and driving it with a heavy hammer into the smoothed bank. After the box was filled, long steel knives specially shaped, a small

Fig. 4. Henry Gardiner brick yard, southeast corner of Pit 3, position (b), Little Ferry, New Jersey.

The uppermost five feet exposed in this view consists of the "Yellow Loam" deposit with a horizontal strip of gray clay, two inches thick, near its center. Blue varved clay occurs below where the tooth marks of the electric shovel are in evidence. The datum plane and other varves being inclined to the south, their truncated edges are in contact with the base of the overlying "Yellow Loam."

mattock and small spade were used in freeing the sample. After being trimmed to the size of the tray, the specimens were wrapped in oil paper and newspaper and transported to the American Museum. The sample sections were then exposed to the air in the laboratory for two to three days to permit a certain amount of the water content to evaporate. They were then immersed for about five seconds in a glycerine-water bath of proportions 1 to 5 to prevent shrinkage. This dipping process was repeated from day to day for a week or more, when the water-air spaces became filled with glycerine. In the meantime, small pins were inserted in the clay samples to denote the limits of each varve, larger pins for every tenth varve and black-headed pins for every fiftieth varve above and below the chosen datum plane.

To insure a ready and permanent method of notation, one end of each tray was tramped with a number, and this numbered end was always placed uppermost when saiving for a sample. Such a method greatly facilitated the subsequent orientation of dech specimen.

In taking a series of samples, the normal amount of overlap of one tray on another was two inches. Due to various contingencies in the field, however, the overlap was frequently more, but wherever it varied from the normal, a field record of it was kept. In the laboratory, the field record was checked by matching the varves before definitely plotting the relative position of the samples on a large-scale working chart.

A CONNECTING LINK.—The most interesting pit sectioned was Pit 3, Fig. 3. In the southeast corner of this pit, lying nearest the river, the distant one in this view (see also Fig. 4), a record of 2,000 varves was obtained. Starting at the base, the section continues up through the datum plane to and including the four prominent gray calcareous varves noted in Pits 4 and 5 at the +910-year level. Without this section, it would have been impossible to establish the stratigraphic relation of the varves of Pits 1 and 2 with those of Pits 4 and 5, for a gap of 250 years intervenes between the highest varves of the more northerly pits and the lowest exposed varves of the most southerly one.

THE OVERLYING "YELLOW LOAM."—In the publications of the New Jersey Geological Survey, the overlying sandy deposits have been referred to as the "Yellow Loam." Fig. 4 shows five feet of this deposit at the east end of Pit 3. This is a typical exposure. A two-inch layer of horizontally banded grayish clay, which was persistent in all of the exposures examined, occupies a central position in the view. The sands, however, above and below this horizon were somewhat variable in different localities. In certain places some of this material is composed of wind-blown sand, but most of it apparently represents bottom-set beds which were deposited in the lake basin after the ice had disappeared, and the region was gently uplifted.

THE COMPOSITE SECTION.—In no one of the five open pits studied at Little Ferry was a complete section of the clay exposed. However, by an accurate and precise matching of the successive varves in the various samples, a composite section of 43 feet of clay was established, Fig. 5. The top of the clay throughout the district is apparently level to the eye, but my studies revealed that it is uneven, for, following deposition and progressive uplift towards the north, erosion removed more clay from the northernmost pits than it did from the southernmost.

The orientation of the numbered clay samples from the Little Ferry district appears on the correlation chart, Fig. 5. To arrange the entire exhibit as a single page illustration, it was necessary to sever the section near the middle and place the halves opposite each other. The lower portion of the section occupies the upper half and the upper portion the lower half of the diagram. The zero year, or datum plane, appears at the right end of the upper half, and at the left end of the lower half of the section. This datum plane is present in only three of the pits, namely: 3, 4 and 5. It has been eroded in Pits 1 and 2. In the 24 feet of clay below this datum plane, 1,100 years, with negative signs, have been counted; in the 19 feet of clay above, 1,450 years, with positive signs, have been noted. For the total of 43 feet of clay, 2,550 years have been determined, that is, an average of 50 years to a foot. The varves in the basal foot of Pit 3 have been disturbed and are illegible. Basal samples were not obtained in the other pits. Such deformed layers have been referred to as slidden zones and are indicated on the chart in solid black. The wavy line across the samples

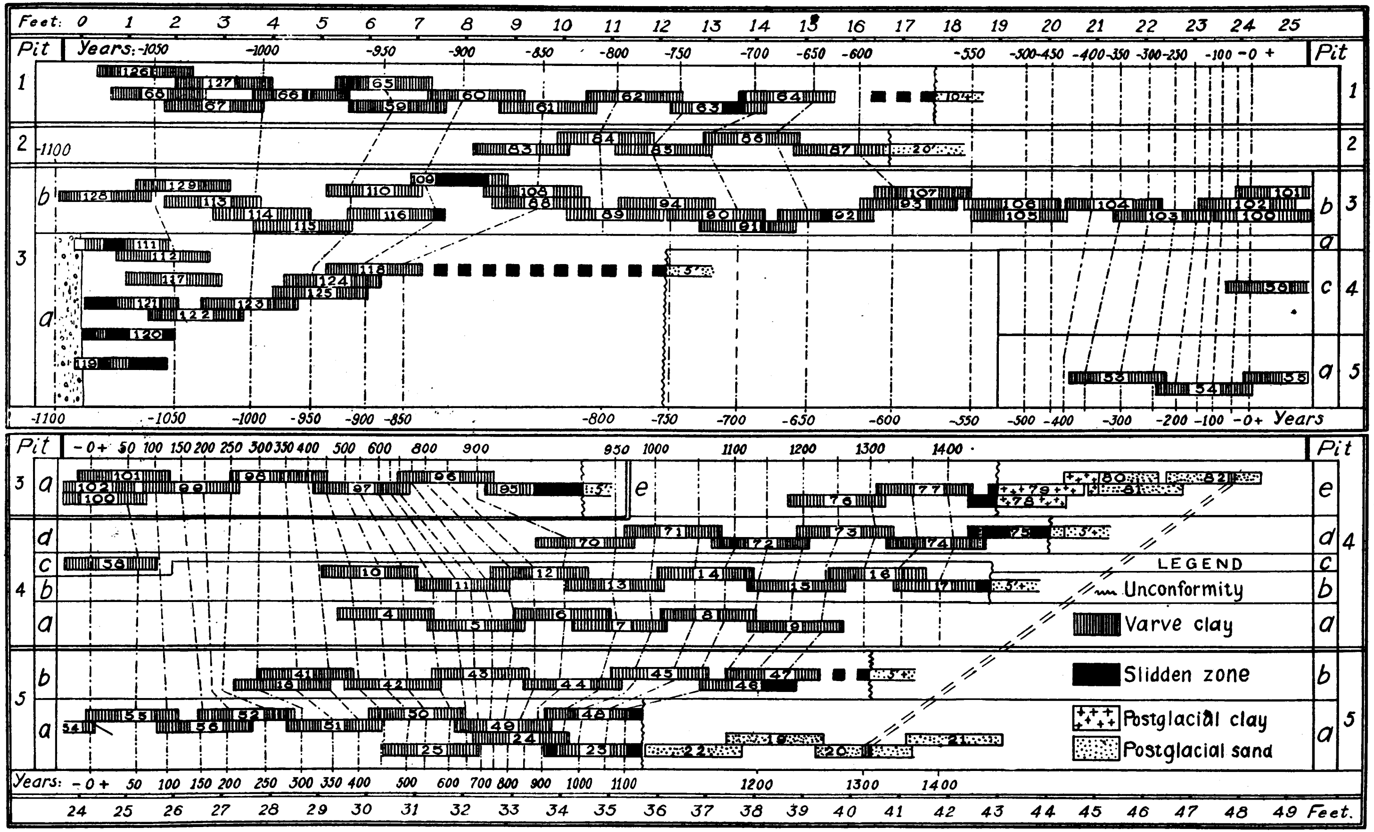

Fig. 5. Composite section of the glacial clay, Little Ferry district, New Jersey.

The section has been divided into upper and lower halves with reference to the datum plane, and the numbered samples orientated as to their respective position in the section.

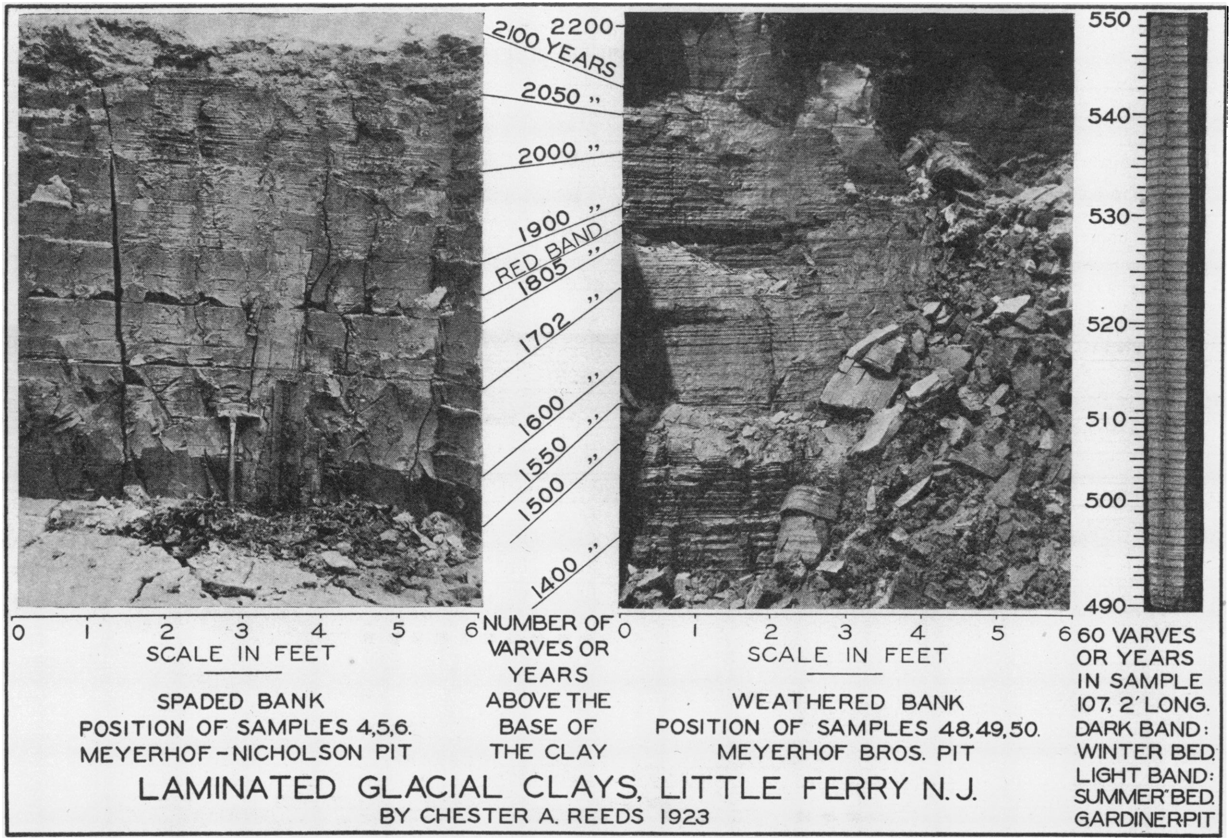

Fig. 6. Three views of the varved glacial clay, Little Ferry district, New Jersey.

Varve correlation has been established between views taken in Pits 4 and 5, while the third is a photograph of sample 107.

at various elevations in the section represents the line of unconformity between the clay and the overlying "Yellow Loam."

SLIDDEN ZONES.—The presence of "slidden zones" in four of the pits offered serious difficulties at first in establishing the number and succession of varves in the composite section. It was discovered, however, that these "slidden zones," which appear as contorted layers, a few inches to over a foot in thickness, do not appear at the same level in the different pits, and consequently are limited in their extent. They are due no doubt to local sliding of a portion of the clay over the underlying mass. This discovery of the local nature of most of these "slidden zones" is of general importance, for "sildden zones" are reported to occur in almost all clay deposits. They are frequent in the Connecticut valley, in Lake Passaic and elsewhere, but they are usually discounted. After we had placed our samples in juxtaposition, and established the correlation of the varves by the individual characters of each varve, such as thickness, color, special banding, composition, etc., it was easy to pass around a "slidden zone" by jumping from the varves in one to those in another series.

FIELD AND LABORATORY CORRELATIONS.—Photographs of many of the typical exposures were made in the field at the time the samples were collected, and the laboratory count of the successive varves have agreed so closely with the lines shown in the photographs that I have been able to identify and number the varves on the photographs, although they were taken in different pits. Such a correlation is shown in Fig. 6. The photograph from the Meyerhof-Nicholson yard was taken in Pit 4, position (a), while that from the Meyerhof Brothers' property, which is a half mile distant, was made in Pit 5, position (a). As some 500 varves are common to both views and no "slidden zones" appear, it was possible to establish the correlation without difficulty. The "red band" near the middle of the views was a conspicuous feature not only in the field but also in the samples. It may be noted from the connecting lines that the varves in the Meyerhof-Nicholson pit are coarser than those in the view from the Meyerhof Brothers' pit; this is attributed mainly to the fact that the position in the Meyerhof-Nicholson pit is nearer the Hackensack River, which was evidently the main channel for transporting the material from the ice front through the waters of glacial Lake Hackensack.

PHOTOGRAPH OF A SAMPLE.—Along the right margin of Fig. 6 appears a photograph of sample 107, which was taken from the Henry Gardiner yard, Pit 3, Figs. 1 and 4. The dark lines across this view represent the "winter" bands, while the intervening thicker and lighter zones are the "summer" layers. The section shown in this sample covers 60 years from varve 490 to varve 550 above the base of the composite section, or —610 to —550 below the datum plane (see Fig. 7).

CURVE OF THE VARVES.—In figures 7, 8, 9 and 10 the thickness and time involved in the deposition of each individual varve have been used as bases for developing a curve of the varves. This graphic method of representing the thickness and relation of the varves was developed by De Geer in his study of the varve clays of Sweden, and it has been used subsequently by other students. On the curve the time element in years has been arranged along the abscissas (horizontal distances), while the thickness of the varves, which varies from year to year, has been entered on the ordinates (vertical lines). The curve shown here is one half the size of the original measurements.

In developing this curve, which has been averaged from curves drawn for each individual sample, the marked variation in thickness of the same varve in different

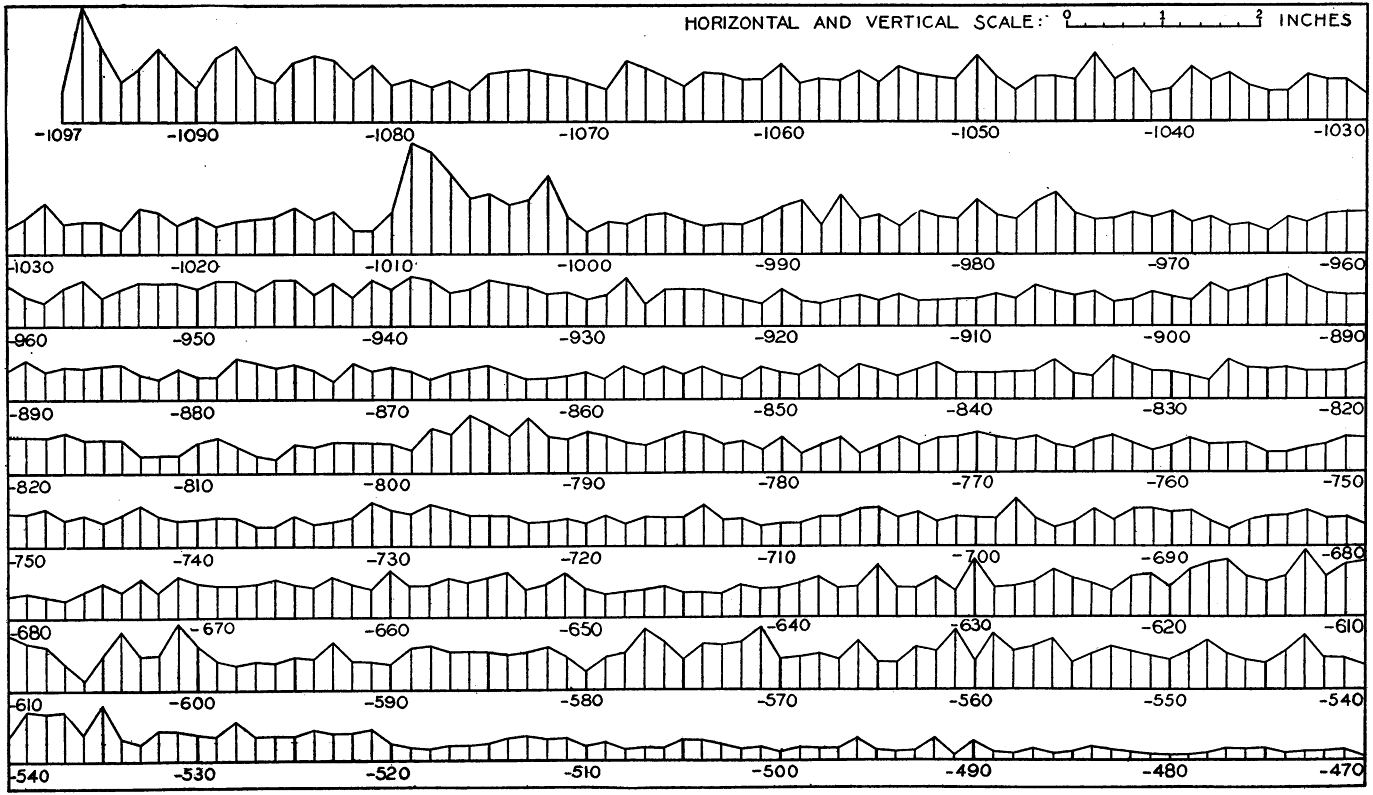

Fig. 7. Averaged curve of the varves, —1097 to —470, Hackensack valley, Little Ferry district, New Jersey.

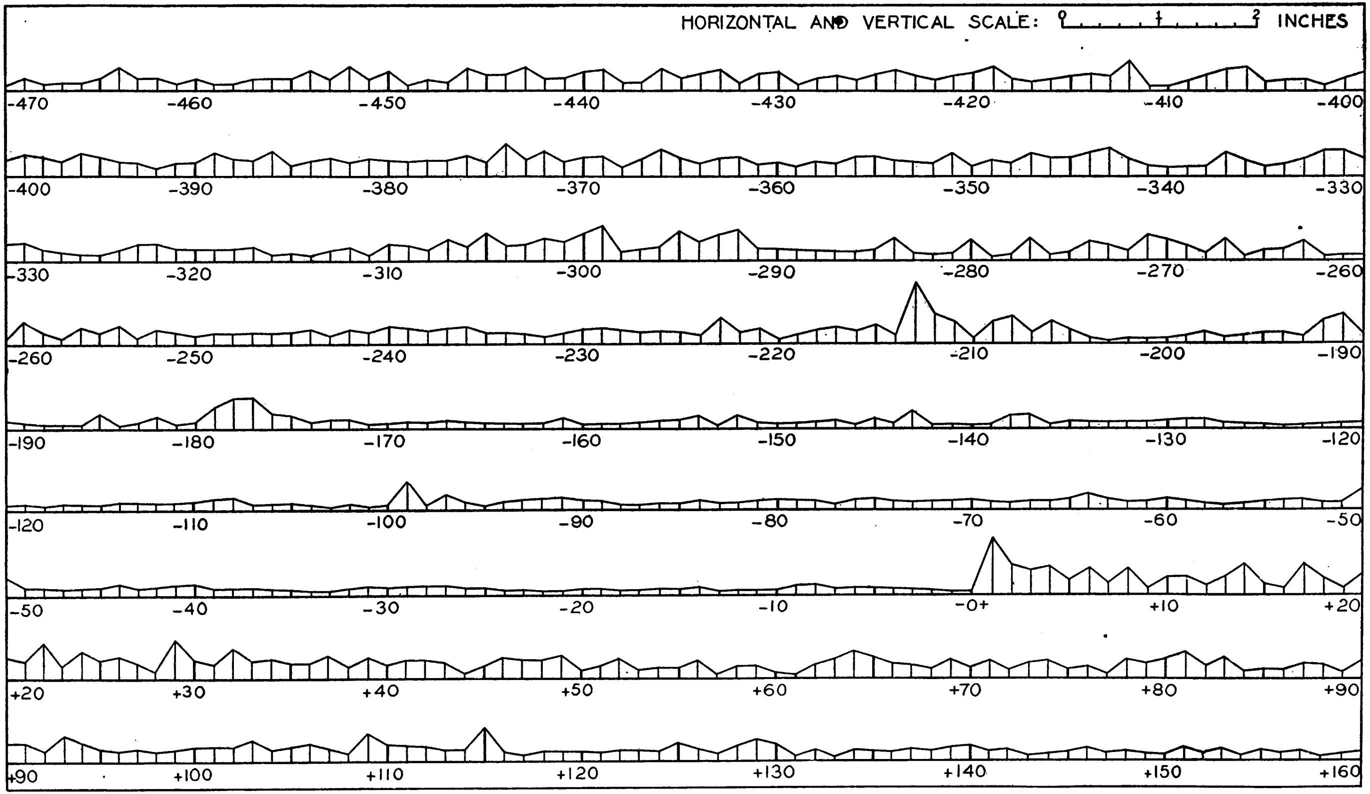

Fig. 8. Averaged curve of the varves, —470 to +160, Hackensack valley, Little Ferry district, New Jersey.

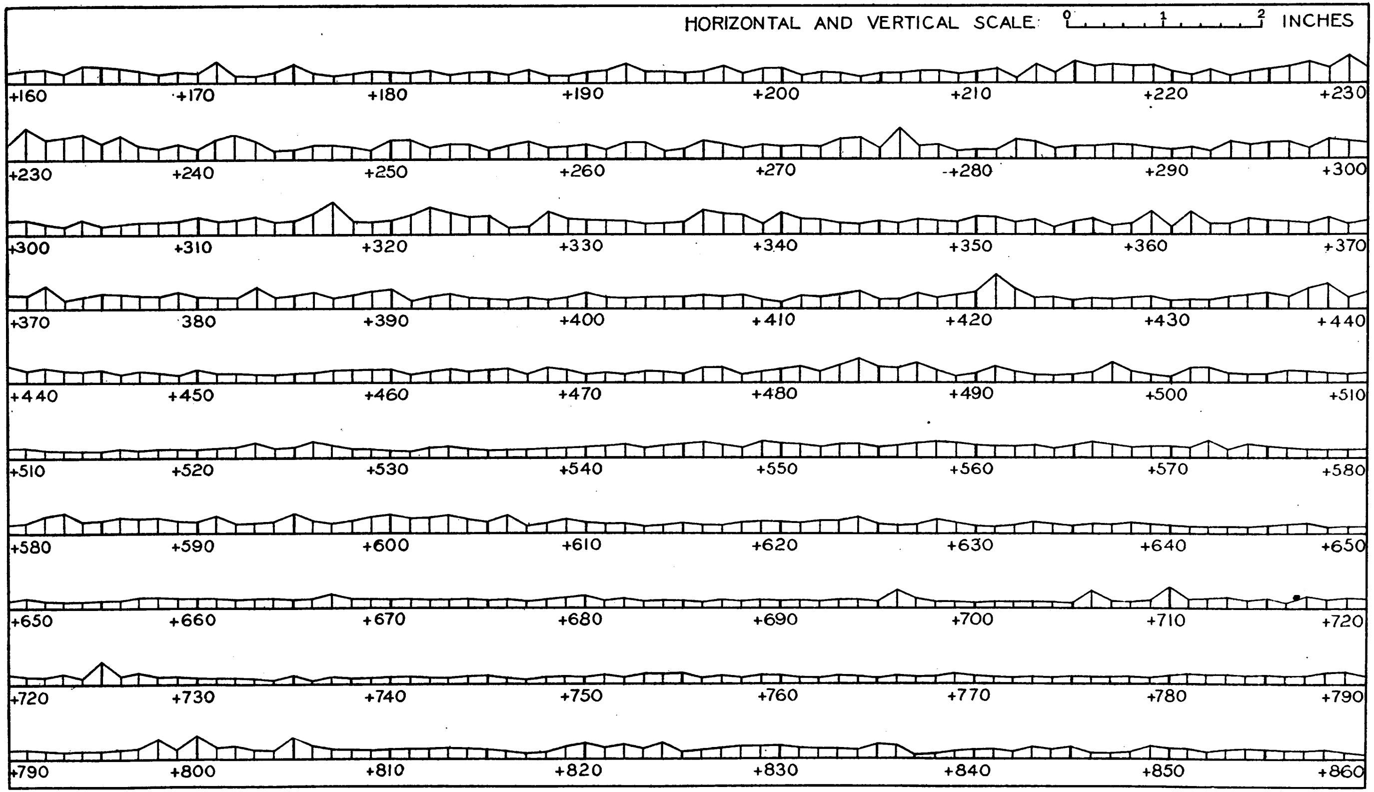

Fig. 9. Averaged curve of the varves, +160 to +860, Hackensack valley, Little Ferry district, New Jersey.

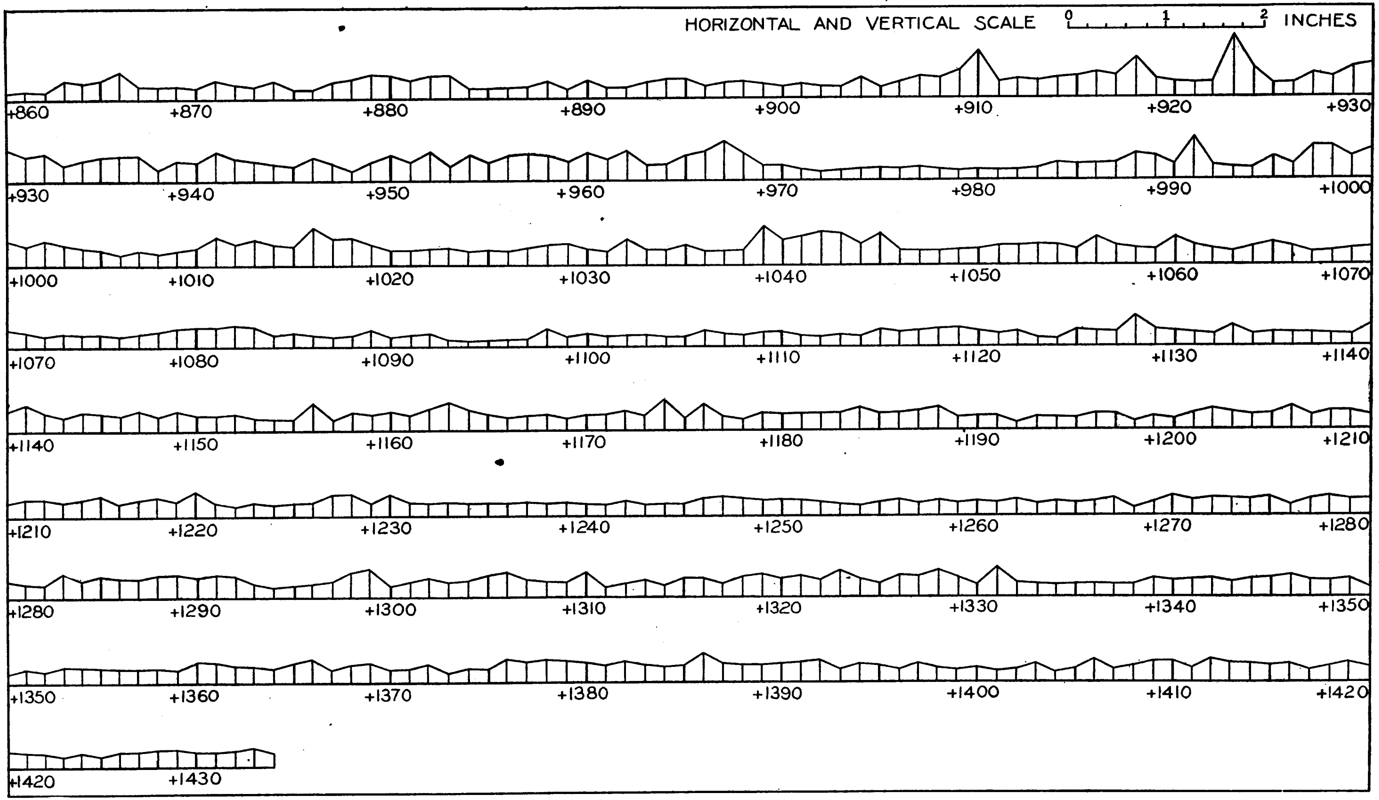

Fig. 10. Averaged curve of the varves, +860 to +1434, Hackensack vallev, Little Ferry district, New Jersey.

samples is not represented, but the resultant mean shown here affords a better basis for correlating the varves in this basin with a contemporaneous series in an adjacent basin. The actual number of individual curves averaged for any portion of the combined section may be ascertained by noting the number of samples containing any one of the 50-year intervals entered on Fig. 5.

The local datum plane, or zero varve, appears on Fig. 8. It is preceded by a long series of very thin varves, and followed by a like number of relatively thick ones. As on the correlation chart, Fig. 5, negative signs have been assigned to the varves below this datum plane and positive signs to those above. The varves in the basal foot of Pit 3 have not been entered, as they were too much contorted to be counted accurately.

The varves —1097 to —520, in the lower portion of the section, are much thicker than those above. This may be attributed to a greater degree of melting and influx of material, but it should also be noted that the ice front or source of supply was much nearer the Little Ferry district during this stage than later. Various cycles of melting and sedimentation may be observed in various portions of the curve, and while some attempts have been made to explain them, it has been realized that their full significance cannot be satisfactorily determined until the studies of the entire Hackensack basin and adjacent areas have been completed.

CONCLUSION

The study of the varve clays of the Little Ferry district, New Jersey, has revealed a period of 2,550 years for their deposition, and thrown a flood of light upon the late glacial history and geography of the Hackensack valley and adjacent basins. In addition to the samples which have been secured for museum purposes, a key section has been established in the Hackensack valley that will assist greatly in the study of the twenty-five miles of territory to the north and to the south of Little Ferry. These areas contain no open pits, and, furthermore, they are covered by more recent sandy sediments locally known as the "Yellow Loam." When these districts have been sectioned with boring tools and a like series of samples secured, the extent of the varves in the Little Ferry district and the rate of the retreat of the ice can be accurately determined. Such work will no doubt double the number of varves represented at Little Ferry.

The varves of the Little Ferry district being more southerly than those studied in any other American locality, they must be added to the known record rather than correlated with a previously determined series. The upper and lower limits of each varve are so precise and the composite section so full that the troublesome "slidden zones" have been identified as local features. The detailed study, in fact, has revealed conditions which were not realized before, and no doubt when the investigation of the entire Hackensack valley has been completed, additional data, equally interesting, will be found.